# LLOYDS REGISTER STAFF ASSOCIATION

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*of the*

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*Lloyd's Register Staff Association*

# LLOYD'S REGISTER STAFF ASSOCIATION: THE PAST AND THE FUTURE

J. B. Davies, D. Gray, E. W. Venner and
J. G. F. Warris

Paper No. 1. Session 1970-71

FOR PRIVATE CIRCULATION AMONGST THE STAFF ONLY

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Hon. Sec. T. Swiatecki
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# LLOYD'S REGISTER STAFF ASSOCIATION: THE PAST AND THE FUTURE

## HISTORICAL NOTE

Lloyd's Register is a Society which is not particularly noted for preserving the evidence of 200 years or so of its existence and achievements. If an examination is made of the successive catalogues of the library which have been produced from time to time, it will be noticed that some books, including incunabula, have inexplicably vanished. Little evidence of a history such as ours decorates the walls of our various rooms and offices throughout No. 71, whereas had we been so disposed, we could have had collections of memorabilia which would now be the envy of the National Maritime Museum; but perhaps this freedom from historical encumbrances could now be regarded as a good thing. However, the purpose of the present Paper is to review 50 years of existence of the Staff Association, assess its success or otherwise, pay our respects to those who have made such an Association possible, and then, what is perhaps more exciting, to consider the next 50 years.

Apart from the Transactions the historical evidence available for half a century of activity is sparse. There exist some attendance figures, a few random jottings, some memories, and little else. We must therefore largely construe what has been the achievement.

It seems that the formation of the Staff Association was first formally proposed in 1919, at which time a meeting of Surveyors for this purpose was held in London. But this was not the first sign of activity. We know that technical meetings were held, and papers read, some considerable time before this date in Glasgow. It seems very likely therefore that there have been other times and places since 1760 when the technical staff met together in an endeavour to organise the presentation of papers on a more regular basis. However, 1919 is the year when our extant material evidence begins. At that time a small committee was appointed to consider the formation of an Association and draft the rules which would govern its affairs. A little later the proposed rules were accepted; they were very similar to those which are now in force. The rules state that the object of the Association is the advancement and dissemination of knowledge in shipbuilding, marine engineering, and other matters of technical interest by the preparation and discussion of communications on the various aspects of the subject. It seems evident from the albeit scant evidence available that these objects have been achieved. Thus we can say that in those early days (or indeed now) there was a need for such an Association, and it must be placed on record that the necessary financial backing was, and is, readily provided by the Committee of Lloyd's Register.

A second meeting was held in 1919 on the 17th May, when it was resolved that the Lloyd's Register Staff Association should be formed, the proposed Rules adopted, and a committee elected which should be composed of:—

4 Surveyors from the Chief Ship Surveyor's Staff
4 Surveyors from the Chief Engineer Surveyor's Staff
2 Surveyors from the London Outdoor Staff.

At that time it was also decided that U.K. outports should be asked to appoint one or more members to act as local representatives of the Staff Association Committee. These representatives would be expected to take an active interest in the affairs of the Association, obtain and circulate the papers, put forward suggestions, and generally keep alive the interest of their colleagues in the Association.

The first provisional syllabus for the coming session 1919/20 was put forward, and whilst this was almost completely complied with, the session was inexplicably delayed for one year, and the inaugural meeting was held on the 6th October, 1920. Eight papers were presented, two by Surveyors from outports.

The first President of the Association was Mr. Watt who at the end of the first session reviewed the work done so far by commenting on the variety of subjects discussed, and the standards established as being those which should be maintained in future sessions. This was largely done.

At the first Annual Meeting Mr. Watt forecast that papers would gradually form an invaluable work of reference for the future. Such a forecast has proved to be correct. Obviously Staff Association papers must decrease in value with the passage of years, but it is true that there have been papers which have proved to be of inestimable value for long periods of time.

Thus at the end of the first year of the Association's existence, confidence was established in its future. From that time the outports took an active part in the affairs of the Association. Papers were read on the North East Coast as well as in London. Other outports expressed their sincere interest in the aims of this new body.

If one looks through the volumes of Transactions of the Association it is difficult not to be impressed by the scope of the subjects covered in the papers and the depth in which many of them were discussed. Although, as has been mentioned, many of the papers suffered the depredations of time, it must be borne in mind that when written they were very valuable indeed.

As with any Association, fortunes fluctuate; there were times when enthusiasm was at a very low ebb. A good yardstick here is to consider the attendance figures over the years, but over the last decade there has been little to complain of. (*See* Figure 1). The success of an organisation such as this one depends fundamentally on its members being convinced that its existence is important. To achieve this requires a vigorous and enlightened governing committee. So far as we can tell the Association has been fortunate in this respect. Much effort has been spent in promoting a fruitful existence spanning 50 years. Most of this endeavour has been unsung and unrewarded. It is beholden upon ourselves, the present members, to offer our thanks for half a century of most valuable service. Having said that we must now consider the next 50 years.

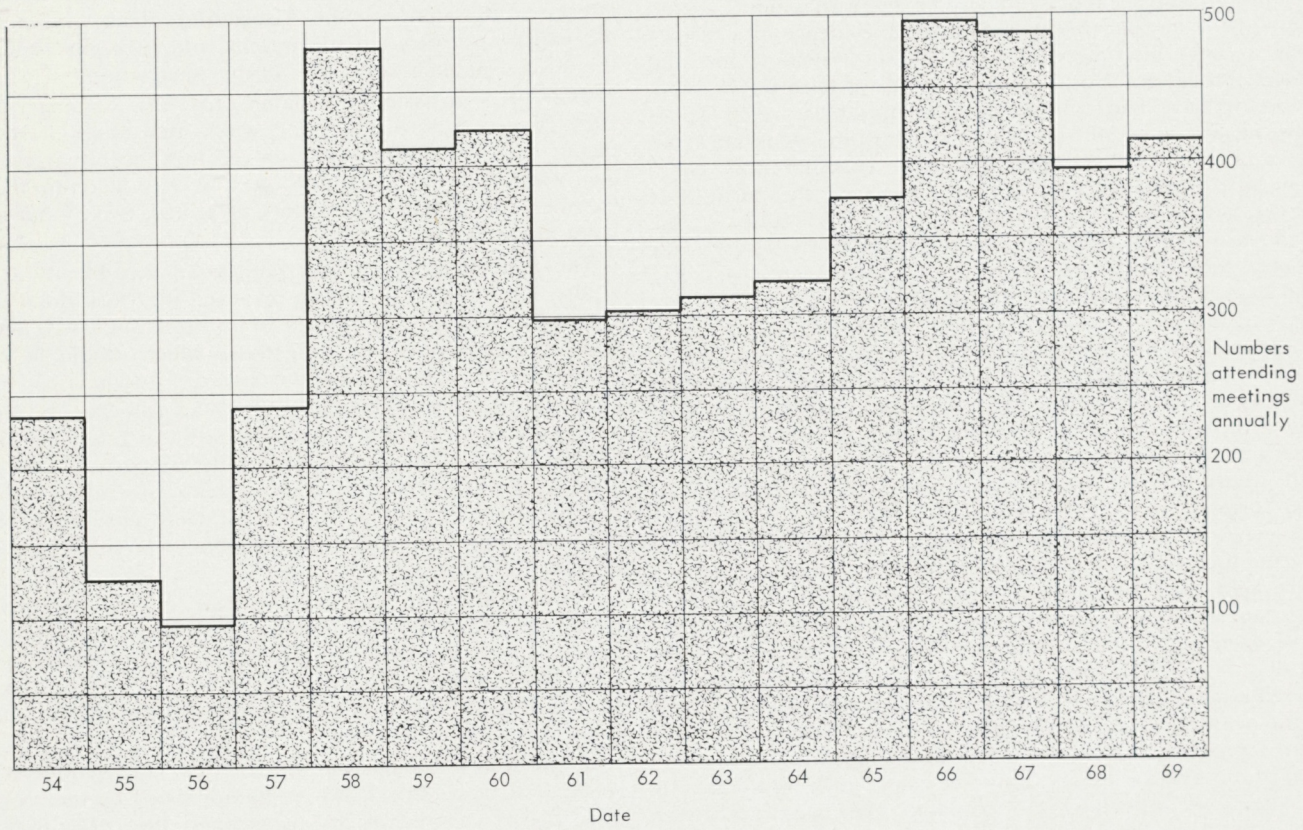


FIG. 1

Annual attendance figures.

# THE FUTURE OF THE ASSOCIATION

**J. B. DAVIES** (Glasgow)

The change in the generally accepted meaning of some fairly common words which has taken place during the past 50 years is well illustrated by the name of our Association. Anyone who today was forming a body to fulfil the objects laid down in our rules would possibly call it "L.R. Technical Association", and conversely a newly-formed "L.R. Staff Association" would certainly have very different aims from our present Association.

Is our name wrong, are our aims wrong, or are both wrong? I would suggest that long before our centenary meeting in 2020 we will have both a "Technical Association" and a "Staff Association" as completely separate bodies fulfilling very different needs.

**Lloyd's Register Technical Association**

It is, I think, a fact of life that it is becoming increasingly difficult to obtain suitable papers for publication; this does not only apply to our own Association, for my own experience on the Publications Committee of a well known Institution shows that very few papers are "offered" for presentation. The Chairman says "Well, we need six papers. We've one that was promised for last Session but was never finished; I think we'll get that" . . . a long silence . . . someone says "The container berth's been in operation for a year now, we ought to be able to persuade someone to give us a paper on it". So, laboriously, a programme is compiled.

Under these conditions is it worth attempting to keep a small technical society in being? Should one not simply recognise that the attractions of television, the open (?) road, etc. (coupled with the increasing strain involved in simply getting to and from one's office), have killed any interest in getting down to the hard work involved in writing a paper in one's own time.

Certainly, attention must be paid to this view, but I hope to show that the continuance of an L.R. Technical Association will serve a most worthwhile purpose both for the Society, and for the Staff.

From an examination of our programme over the past few years it can be seen that the vast majority of our Authors are writing on the subject of their day to day official duties. These papers may either provide background information to Rule revisions or maybe a collation and amplification of all the requirements for a particular subject. Such papers as Pumping and Piping by Clayton; Beckwith and Gray on Tonnage; or Simpson's recent paper on the 1966 Load Line Convention (to name only a few) are of enormous help to an outport Surveyor.

It can be argued that if these papers are of such value then they should be prepared officially and issued as "Instructions to Surveyors". There is much force in this argument, but there are also disadvantages, and I would suggest a compromise is necessary. If the subject is first dealt with as a Staff Association paper, then questions can be asked and opinions expressed in a way that cannot be done if the same text was issued as an official Instruction. These questions may well show up areas where amplification is desirable or the wording is capable of misunderstanding. Further, the preparation of any official Instruction is bound to be a lengthy process since, being official, the draft Instruction must be circulated to every department which might be concerned.

On the other hand, since a "paper" is the opinion of an individual it cannot be quoted officially as justification for action taken, nor is there any system for ensuring that the information is kept up-to-date. The first is, perhaps, more an academic point than a practical one, but the second can seriously detract from the long-term value of a paper. To get over this difficulty I would suggest that once the discussion has been replied to by the Author, the paper should be amended as may have been shown necessary, reprinted and issued to all Surveyors as an official "Guidance Document". It would then be the responsibility of the particular Head Office Department concerned to ensure that amendments, etc., were issued, and the publication would be on the same footing as Instructions to Surveyors, Circulars, Plan Approval Letters, etc. Obviously this would only apply to a proportion of our papers, but I think it will be an increasing proportion, and I see the main function of our Technical Association as being the production of this type of paper.

So much for the type of paper we may have. Any paper can be improved by a good discussion, and when I was Secretary of this Association some years ago I sometimes felt it was nearly as difficult to get contributions to the discussion as it had been to get the original paper. This applies particularly to written contributions, so the obvious answer is to arrange meetings at outports for the discussion of the paper; such meetings should be regarded as a normal routine procedure and not as something unusual to be arranged as a very special occasion. I am not suggesting that this should be done in every port for every paper, but very much more should be done in this respect than has been done up to the present.

It has been our aim to have enough papers to provide for regular monthly meetings throughout the winter, but this is obviously a strain on our resources, and the number of meetings could well be reduced. Better a few well-attended meetings discussing good papers than scrounging around to get papers (and an audience) just to make up the numbers.

The membership of the Association is, officially, limited to "the Technical Officers of Lloyd's Register of Shipping", but despite this, papers on the administrative and accounting procedures should be encouraged. Many of these are even more peculiar to the Society than are the technical problems.

To sum up, I visualise the present Staff Association (renamed the Technical Association) largely as providing a forum for the unofficial discussion of what will later become official documents.

**Lloyd's Register Staff Association**

There can be few organisations (if any) where the staff relations have been—and are—as good as we have. Nevertheless times are changing and, in particular, the numbers of technical and clerical staff have increased so rapidly that I think there is a danger of the old informal system breaking down. The meetings of outport representatives before the Pension Fund Annual Meeting provide an opportunity for raising some matters, but this is limited to the U.K. staff and, in any case, the discussions here frequently have to be limited to only that part of a problem which is within the scope of the pension fund. The mere fact that discussions do have to be so restricted is, in itself, an indication that the opportunity for meetings with a wider agenda would be appreciated.

**D. GRAY** (Headquarters)

## 1. Introduction

Before attempting to forecast the future of the Staff Association it is necessary to pinpoint its purpose. This is defined in the rules printed on the back of each annual programme as follows:

"The advancement and dissemination of knowledge in shipbuilding, marine engineering and other matters of technical interest by the preparation and discussion of communications on the various aspects of the subject".

It is also convenient to review the circumstances in 1920 and the present day.

## 2. Circumstances in 1920

(a) COMMUNICATIONS in 1920 were relatively slow. The postal system was the main system used for the written word; in this context it must be pointed out that a time interval of four or five months was by no means unusual between enquiry and reply between Headquarters and, say, the Far East or Australia. Cables were expensive and were used relatively infrequently. Telephones existed but were not used with the readiness of today. The telex system did not exist.

Visits by the Headquarters staff to outport offices had to be made by train or ship.

All these considerations lead one to conclude that "communication" between Headquarters and outports, and between outport and outport, was relatively slow.

(b) TECHNOLOGY AND TRAINING

In 1920 the rate of technological advance was slow by comparison with today and, what is probably more important, there was probably little interpenetration of techniques.

The standard solutions to problems quoted in Rule requirements were complied with, since they reflected current and well established practice. In all probability there were few cases of dispensation from a Rule requirement.

This meant that a surveyor taken on to the staff and adequately trained could expect to be trained for life in one single package deal. The pace of updating in their subject was slow.

## 3. Circumstances in 1970

(a) COMMUNICATIONS have increased beyond all measure since 1920. The postal system still exists as does the cable system; the former has been speeded up, of course, by the use of aircraft. However, these are not the only media for the written word. The telex system is cheap, is widely used and will be used more in the future. Transfer of information by facsimile equipment is available today and will be used to an even greater extent in the future.

The telephone system to-day has outstripped that of the 1920's by an immeasurable margin. One telephone engineer in the U.S.A. has estimated that if the automatic dialling system had not been introduced, then every girl in the U.S.A. would be required to operate the telephone systems in that country in order to provide the same telephone facilities that exist to-day.

The video telephone will be available in the forseeable future, thus removing one of the disadvantages of the telephone system which has existed up to now.

Picture transmission by television systems is here today; it is no longer science fiction, so that it is within the realms of probability that a pair of eyes in Headquarters may be able to give advice or to pass judgement on a problem faced by an outport surveyor.

Air travel both existing and proposed is such that visits between Headquarters and outports and vice versa are quick, easy and can be arranged at little more than a moment's notice.

(b) TECHNOLOGY AND TRAINING

More and more technologists are finding it necessary to run faster and faster simply to remain in the same position. No longer can a technologist expect to be trained for life in a single package deal at the outset.

In addition to the rapid rate of advance in all technologies, new technologies are arising and old ones are passing. What is probably of even greater importance is the interpenetration of techniques in every field. The control engineer penetrates into all fields of technology; the naval architect working in the tanker field must understand the hidden dangers of static electricity; the mechanical engineer must realise the necessity for producing suitable engine characteristics so that the electrical system may function satisfactorily; all disciplines must be able to appreciate the principles of and the necessity for instrumentation as designers move further and further towards critical conditions in their attempts to improve efficiencies.

The problem of updating and retraining surveyors in order to keep abreast of advances in technology can perhaps be divided into four categories:—

(i) Attempting to keep abreast in the field of his own specialisation.

(ii) Extending his knowledge to fit him for advancement in his own field.

(iii) Re-training to allow him to transfer from a dying technology to a new one.

(iv) Maintaining his general education and his attitude to continual change.

Of these the most difficult from the psychological point of view is the retraining problem. A man who is expert in his own technology – a senior man perhaps – finds great difficulty in starting at the beginning in a new field where he may be in competition with younger men.

The Society is responsible to a great extent for looking for and implementing solutions to these problems. This is so because intellectual capital is as much its investment as is capital spent on offices and laboratories. The surveyor too is responsible because the value of his technological services must be maintained and increased if his earning power is to grow.

In the past the surveyor has been left very much to maintain his own professsionalism. This will continue but means can, and must, be provided to help him.

(c) PARTICIPATION BY THE STAFF

The writer is not competent to judge whether there was enthusiasm in the past by staff members to take an active part in the work of the Staff Association. However, since the Association was brought into being only in 1920 and became firmly established, it can be concluded that there must have been a considerable amount of enthusiasm among staff members, together with active participation in the running of its affairs.

Anyone who has had any personal connection with the Association in recent years is well aware of the difficulties

that face the committee with regard to arranging programmes. These centre principally around the production of suitable papers and written contributions.

The reasons for this are not hard to locate and the following are probably the main reasons.

(i) Most surveyors located in major cities are faced with commuting problems. Travelling times of up to two hours per day are by no means uncommon, often under arduous conditions; in the case of staff located in London and other large cities the travelling conditions are almost intolerable. This, added to an eight hour working day, means that a surveyor has little enthusiasm for writing a paper for the Staff Association in his own time.

(ii) Extraneous activities outside his professional working life play a large part in a surveyor's life, far larger than 50 years ago. These extraneous interests include television, motoring, and do-it-yourself repairs to the home (frequently forced on to the man because of the high cost of hired labour and/or the difficulty of obtaining such labour).

(iii) In all countries—the increasing activities of the "welfare state". Whilst not attempting to decry the welfare state it is the author's opinion that these activities tend to breed an attitude of mind which expects that, whatever the problem, a benevolent authority – central government, local government or the employer – will produce the solution. Pushed to the limit such an attitude of mind regards personal initiative as neither necessary nor even desirable. The preparation of a contribution for the Staff Association requires initiative and effort. The effect of this is seen in other walks of life, golf clubs, tennis clubs and the like. Prior to World War II membership of "the committee" was regarded as an honour, so much so that lobbying for election was by no means unknown. To-day it is difficult to obtain volunteers for such posts.

(iv) In recent years there has been a tremendous increase in the number of technical journals, technical magazines and the like, so much so that it is almost impossible for any man to read and assimilate all this information in addition to working an eight hour day. In consequence, many men are reluctant to write papers which add to the volume of technical information passing over their desks.

(d) The Work Load

(i) Headquarters

The following figures denote the total number of plans dealt with in the engineering departments, dealing with plan approval, in Headquarters.

| | 1960 | 1969 |
|---|---|---|
| Electrical Engineering Plans | 10,286 | 19,682 |
| Control Engineering Plans | Nil | 14,726 |
| Other Engineering Dept. Plans | 47,260 | 87,544 |
| Total Plans | 57,546 | 121,952 |
| Total Ships classed | 703 | 644 |

These indicate that the number of plans per ship is increasing with the years. The main reasons for the increase are the increasing complexity of machinery arrangements, the desire on the part of designers to improve efficiency, and the offering of new or novel machinery arrangements which will solve the problems pinpointed by the Rules. All these features represent information which is lodged in Headquarters. The local outport surveyor has knowledge only of those cases which have passed through his hands.

(ii) Outports

The nature of the work and the work load of the outport surveyor has also altered over the years. Mr. O. Nilsson in his paper "Some Notes on the Hull Survey of New Construction in Sweden" (Session 1969/70) highlighted a major problem when he pointed out that with present speeds of ship construction it is not possible for the surveyor to carry out the same work, or do it in the same manner, as he did in the "good old days" because little interference with operations can be tolerated. It is unlikely that this process will be halted in the future. In the author's opinion it is probable that the outport surveyor's work will shift its emphasis from the survey of specific jobs to type testing of prototype equipment plus examining the system of quality control in the works concerned, leaving survey of individual jobs to the quality control department of the firm.

Changes of a similar kind will occur in the engineering field and, indeed, it is not beyond the bounds of possibility that old established techniques involving accurate machining to close tolerances may be replaced by the use of techniques employing adhesives.

(e) Headquarters and Outport Relationship

In addition, there has been a notable change in relationship between the work of the outport surveyor and the Headquarters staff. Fifty years ago, due to the slow pace of communications, outport surveyors could not wait for the receipt of advice from Headquarters. Decisions were made on the spot by the outport surveyor concerned. In recent years the Society has instituted a team of mobile troubleshooters (Technical Investigations Department) based on Headquarters but available at short notice. The very nature of this work brings Headquarters staff into close contact with the outport surveyor. Such close contact between the two groups has, perhaps, conditioned outport surveyors into asking for advice much more readily than their counterparts of fifty years ago.

A by-no-means unimportant feature of ready access to Headquarters today is when a firm, dissatisfied with a decision made by an outport surveyor, appeals to Headquarters. Unfortunately, it is not unknown for such an appeal to reverse the original decision made. This can result in reluctance on the part of the outport surveyor to attempt a decision in future cases but, instead, to refer problems to Headquarters.

## 4. Summary

What then are the salient features of this comparison of conditions in 1920 and in 1970 and what conclusions can be made?

Communications are now so rapid that Headquarters staff are frequently involved in the day to day work of the outport surveyor. This tendency will increase.

More and more information is being lodged in Headquarters. This tendency will also increase.

It will be more difficult in the future for a surveyor to work in his own time for the benefit of the Staff Association.

There must be more training and re-training of surveyors. In this context it may not be out of place to mention that the training bill for the Alfred Holt Company is not less than 6 per cent of the wage bill; in the British and Commonwealth Shipping Company with an engineering annual wage bill of $£1{\cdot}7 \times 10^6$ the training bill is £160,000, i.e. more than 9 per cent.

**5. The Future**

How can the Staff Association fit into the problem pattern posed above? In the author's opinion the *modus operandi* of the future could well be as follows:

(a) Dissemination of Knowledge held in Headquarters

The knowledge lodged in Headquarters requires collation, preparation and dissemination. This should be an official task carried out, and paid for, during working hours.

(b) General Shipping Matters

There is a need for papers about the marine industry in all its aspects, and not necessarily confined to classification matters. They would cover topics which are of interest to surveyors because they are employed in the marine business and not necessarily because they are naval architects, mechanical engineers, electrical engineers, control engineers, or metallurgists. Economics must be tackled in this area because improved economics are normally the springboard of technological innovations. In all probability most contributions in this area would require to come from invited authors and paid for.

(c) Specialist Subjects

Because of the increased interpenetration of technologies, knowledge of the basic principles of specialist disciplines must be disseminated to all surveyors. The task could be undertaken by specialist members of the staff, wherever located. It should be an official task carried out, and paid for, during working hours, and shown in the total training bill.

(d) Reports by Departmental Heads and Heads of Outports

There is a need for reports by departmental heads or heads of outports explaining the philosophy adopted in the running of the department concerned. Such philosophy is essential when Rule amendments are proposed or when Rule requirements are prepared for new projects such as drilling rigs, air-cushion vehicles, underwater vehicles, containers, etc.

Such reports should not be confined to technical departments. Non-technical departments should also be included.

As a result of this it could well be that some surveyors may be enabled to see the Society as a whole for the first time in their lives.

(e) Private Contributions

Finally, the private contribution on which the Staff Association has existed for the past 50 years. There must always be room for any surveyor who has the energy, initiative and the ability to write a private contribution.

**E. W. VENNER** (Headquarters)

As a non-member of the Staff Association I greatly appreciate your invitation to contribute to the first paper of the 1970 Session and I congratulate the Association on the occasion of its 50th Anniversary.

To consider the future of the Staff Association during the next 50 years is difficult without giving some thought to the future of the Society itself, and its progress into the year 2,000 and beyond. Perhaps I may be forgiven if the bulk of my remarks are concentrated upon the latter question.

In his recent book *The Age of Discontinuity*, Peter Drucker suggests that prediction can be no more than the continuity of yesterday's trends extending into tomorrow. "What has already happened", he says, "is the only thing we can project and the only thing that can be quantified".

I have endeavoured to look back at the year 1920 as my "yesterday"—the year in which your Association was originally formed—and I ask myself whether I would have observed trends by which to predict the many remarkable events which have taken place during the past 50 years and which have had a direct effect upon the Society's fortunes.

Had I been my present age, and standing before you to comment upon the possible position of Lloyd's Register in 1970, I, in 1920, would have been an employee of a Classification Society consisting of some 450 Surveyors, the classed tonnage—predominantly British—amounting to 27 million tons and the largest vessel in the Register Book being the *Bismark* of 56,000 gross tons.

No doubt I would have been conscious of my good fortune in surviving a "war to end all wars" and I would have observed clear evidence of the severe economic depression which followed it, but would I have predicted such devastating effects as it produced throughout the world which would continue for more than a decade?

I may have suggested with some confidence that the British Merchant Fleet would become predominant and that Lloyd's Register would follow the Red Ensign to all corners of the earth during the ensuing 20 years, but could I have prophesied that this development of an assured market would be cut short by another world war within 20 years? Could anyone have predicted that the Society would make great strides in Japan, which would become the leading shipbuilding nation of the world, in an era of technological progress in which tankers of a quarter of a million tons are a reality, and in which the computer, nuclear power, satellite communication, and even journeys to the moon, are no longer a novelty?

The answer gives me little confidence to attempt prediction of the Society's future; and standing here in 1970 and looking 50 years ahead, the year 2020 seems remote indeed. Yet the year 2000 is now no further away than 1940 which is still a vivid experience and barely falls into the category of "yesterday". It is not unreasonable to suppose that the senior management of the Society for the year 2000 is already in business and may already be within the Society's Staff. What sort of organisation will it manage and in what sort of world? Is it right to think wholly in terms of yesterday's trends? Is the growth of the Society likely to continue along the same lines as before? I rather doubt it.

Whilst the Society has made considerable progress during these remarkable 50 years, a noticeable change of style has taken place, particularly during the last two decades. There has been a gradual transformation from a British organisation with overseas offices, towards an international organisation with its Headquarters in the United Kingdom.

This change in character is not yet complete, there being some way to go before the Society can claim truly multinational management which is essential to its future prosperity. It is clear that the growth of Lloyd's Register is likely

to be overseas rather than in the United Kingdom, and the Society must be so staffed and managed as to be ready to meet all reasonable demands and grasp all worthwhile opportunities, wherever they may arise, regardless of cultural, political or other difficulties.

To fully achieve these objectives there must be a greater exchange of staffs between countries than has been the case hitherto. A mere one-way traffic of British expatriates is already insufficient. The policy must aim to produce a top management which is itself multi-national in character but nevertheless concentrated in one headquarters.

The future of Lloyd's Register will be influenced as much by world events as by any long-term planning and, in my opinion, particularly by possible political developments in Europe. I believe that during the next 50 years political as well as economic integration of Europe may well be established, with the United Kingdom participating. Certainly it may be a slow and painful process, but events are moving in that direction. Already the six member countries in the present European Community are co-ordinating their economic policies on lines agreed in Brussels, and whilst there still appears to be a strong sense of nationalism within the European Partnership, this barrier will inevitably be lowered stage by stage. Old institutions and concepts are being challenged by the young, and there is no reason to imagine that nationalistic attitudes will remain at their present strength for another half century.

In Britain there are signs that certain sectors of industry are already thinking in practical terms of European partnership—the Dunlop/Pirelli plan is a case in point, and maybe Lloyd's Register should give more thought to a future within a political community containing some of its most active competitors. It should not overlook the possibility of those competitors themselves effecting some sort of merger, with or without the Society's participation.

Political issues in Europe apart, the advance in all areas of science which vitally affect Lloyd's Register in its present role, coupled with the common needs of clients (manufacturers and operators alike), and Governments, may compel a change of attitude and necessitate the greater pooling of knowledge and information between Classification Societies for the common good.

Whatever the future technical trends may be, one issue is absolutely clear. If Lloyd's Register is to retain its position in the world and possibly its identity, it must recognise that the restricting factor is not likely to be technical, or financial, but the availability of competent, internationally orientated managers, from small port level upwards.

At all levels, management must become as professional in the management skills as in the technical skills. In the past there has been a tendency to concentrate on the latter and to fail even to acknowledge the existence of the former. It is in this area that your Association can play an invaluable role in the future.

The present aim of the Association is contained in the Rules as follows: "The object of the Association is the advancement and dissemination of knowledge in shipbuilding, marine engineering and other matters of technical interest by the preparation and discussion of communications on the various aspects of the subject".

I would suggest that before long technical matters will no longer be the only issues with which the Association should be concerned, not only for the benefit of the organisation as a whole but also for the professional development of the individual member.

There is an increasing awareness in this country and elsewhere that technical education and training is in itself insufficient to produce the manager of the future. It is interesting to note that the most recently published figures concerning professional engineers in the United Kingdom indicate that 65 per cent of the 18,000 covered by a Ministry survey are stated to be employed in administrative and managerial positions, and that one-third of the courses which were attended over a period of 12 months were not concerned with technical issues at all but with business studies including management.

I use the word "management" to mean the controlling activity, and those concerned with it, who must understand the proper use of resources to meet specified objectives. They must be able to identify those objectives and place them in proper priority. They must be able to plan the means of achieving those objectives and, on the basis of available evidence, measure the progress being made and decide upon ensuing action.

In an organisation such as Lloyd's Register, so thinly spread over a large proportion of the world, those who have the authority to make major decisions are remote and unknown to many of the people who are affected by them. Even if the decisions are reasonable, remoteness itself tends to create anxiety and misunderstanding.

In future years there may be less tolerance to such a situation, and a greater degree of management by participation, if not by consent, will be necessary. No amount of communication or other machinery will convince staffs far away from Headquarters that they must accept decisions if it is the judgement of the decision makers themselves that is in question. Assuming the decision makers are fully qualified and good at the job, a great deal will need to be done to bridge the gulf between those deciding and those who benefit—or suffer, from the decisions. Only by participation can there be support for the decision makers, and even more important, will the authority to make decisions continue to be acknowledged. The nature of the authority to be exercised by the appointed representative of the organisation will, I suggest, require very clear definition before many more years have passed, in the form of policy statements covering all areas of decision making. Thus the staff of the future will better understand the limits within which managers can exercise authority and management will agree not to extend those limits without informing the staff.

One day in the future perhaps some Supra-National Authority will emerge to take the place of the increasing number of competitive Classification Societies. In such an event, Lloyd's Register has a unique contribution to make, and provided it were seen to be a dynamic, efficient and multinational organisation, it could itself be appointed as that Supra-National Authority, acting on behalf of a very large number of Governments.

It will only do so if it can think and speak with authority in a host of countries, in other words when it has so trained its staff and its management as to bridge the cultural and political gaps, as well as the professional.

**J. G. F. WARRIS** (Rotterdam)

Although we are celebrating its 50th Anniversary, the Lloyd's Register Staff Association might today be little more than a name to many people in the Society's outport offices,

had it not been for the excellent papers which, through the years, have been presented before the Association and distributed amongst the staff world-wide.

Being myself an outport man, I know from experience that these Staff Association papers are highly appreciated for their informative value by the man in the field.

I think it is also correct to say that the technical reprints which, in the course of time, have been circulated outside the Society have greatly contributed to the reputation of Lloyd's Register as a unique source of technical and statistical information.

I hope that members of the staff will continue to make use of the facilities offered by the Staff Association and to share their special knowledge and experience with their colleagues.

An era of great changes and increasing complexity lies ahead, and no effort should be spared in keeping the staff informed about the latest developments relevant to the Society's affairs, both technical and non-technical.

It is about this future and the part which the Staff Association could play in it that I have been invited to give my views.

Obviously there would be little sense in speculating about the future of the Staff Association without first trying to form an idea of the future of the Society itself.

While there could be differences of opinion regarding the kind of future to which we may look forward, I do not think that there could be any doubt about the continuation of Lloyd's Register itself, for it is inconceivable that we should fail to exploit successfully the Society's tremendous potential.

At the same time, having potentialities alone is not enough, as many firms have had cause to discover, sometimes too late. Unless the available assets are properly identified and managed, the ultimate chances of success are small, for today's highly competitive world confronts us with a road that is full of snares and pitfalls.

Let us take a general look at the obstacles which stand, or could arise, between us and the future which we want Lloyd's Register to have.

I would refer to what has been said and written in recent years about certain developments and trends around us, constituting as many threats to the Society's interests. These threats, which I need not repeat here, are real and their lucid presentation at the time cannot have failed to make an impression on even the most complacent character amongst us.

Acknowledging the existence of these external dangers, there would appear to be very good reason to avoid or rectify possible internal weaknesses like complacency or parochialism, or the lack of essential qualities such as enthusiasm and a sense of urgency.

It is not my intention to make up a list of possible shortcomings against which we should be on our guard. Let it suffice to conclude that the obstacles which the Society may find on its way can be divided into those from outside and those from within, and that our success in overcoming external problems will largely depend upon the measure in which we succeed in resolving the internal ones first.

I suggest that we take a look at the position today and, in my opinion, the picture looks promising.

We are, in fact, participating in a process aimed at transforming the Society into an efficiently operating modern enterprise, justly proud of—though not inhibited by—its long and splendid history.

The transition period is not an easy one and no doubt many people will at times be vaguely bewildered by the nature and rapid succession of the changes which come over us like an avalanche. At the same time, however, most of us soon seem to enter into the spirit of the affair and are inspired to greater activity.

Perhaps one of the most beneficial side effects of this hectic period is that it has shaken us all up and made us realise that we shall never be able to return to a state of relative tranquility and keep Lloyd's Register going at the same time.

Assuming the current renaissance of Lloyd's Register to proceed as planned, I believe that we may look forward to busy times, for the dynamic character of the Society will dictate action to its servants at all levels.

I think that this greater activity will be reflected in a more aggressive attitude towards the further development of current markets and the exploration of new ones.

It is tempting to speculate upon the possible consequences of this new attitude.

Having joined in the mêlée of organisations seeking to expand the scope and depth of their activities, amalgamating with others when this appears to be the next logical step towards further growth, we should perhaps not rule out the possibility of Lloyd's Register merging with another Classification Society to form a regional stronghold.

Nor, perhaps, should we rule out the feasibility of Industrial Services being placed in a more competitive position than it now finds itself, certainly in some countries.

Being allowed to adjust its fee levels to what the market will bear, avoiding excessive differences between countries within areas of roughly similar general cost levels, the overall contribution of income from this department might benefit by virtue of an increase of work.

These are just some speculations, and admittedly bold ones at that, but being prepared to at least consider bold schemes we should find it less difficult to consider and act upon propositions of slightly less consequence. Of the latter there will be many as we shall be directing our attention to ensuring the Society's further growth by systematic marketing and marketing research.

Broadly speaking the three areas in which the Society operates are associated with the winning of raw materials, the processing thereof, and the transportation and handling of goods in the various stages of processing.

With a growing world population and a gradual overall rise in the standards of living creating an increasing demand, it follows that we are operating in a growing total market.

Not a single aspect of this market, however, is static. Old sources of raw materials dry out and new ones must be found, requiring completely different equipment and techniques (think of sea-bed exploration).

Bound by the laws of economics, the entire concept of transport has become and will remain the subject of continuous rethinking, leading to new designs of vehicles and propulsion. New sea ports will require to be built, old ones to be extended, demanding major dredging operations and the manufacture and transportation of equipment of all kinds.

The processing and manufacturing sector will require to be increased in size, geographic spread, and versatility, becoming obsolescent at much shorter intervals of time than is the case at present.

Evidently the cake is growing all the time whilst changing in composition, and I can think of no valid reason why the Society should not be able to secure a satisfactory portion for itself.

Further diversification of our services will be essential not only to increase our business, but also to compensate for unavoidable diminishing returns from certain sources.

In looking for opportunities to promote this diversification all members of the staff, especially the field Surveyors, should be encouraged to participate. Basically, the Society is in business to sell Surveyor hours, and the higher the number of fee earning hours in relation to the number of available Surveyor hours, the healthier our business will be, while our charges can be kept at a competitive level.

Being necessarily limited by the length and purpose of this paper, I have not attempted in the foregoing to do more than touch upon a number of points, some of which could in themselves form the subject of a separate paper.

My conclusions, however, can be fairly distinct. Given the available potential, a growing and only partly explored market, and the kind of management which is currently getting off the ground, the Society could hardly have anything but a successful future.

How successful that future will be is going to depend upon the people who not only work for Lloyd's Register but who, in fact, are Lloyd's Register.

While it is most reassuring to know that the Society is availing itself of the advantages of modern management and of sophisticated technological aids without which we would soon lag behind our competitors, these instruments alone cannot assure success.

In the final analysis, as long as the bulk of our income has to be earned by men who must make decisions on the strength of their technical training and experience, Lloyd's Register will remain very much man-orientated.

It is for this reason that as technology and modern management techniques inexorably extend their grip on the Society, it will be essential to ensure that the Society does not lose its grip on its people in the process.

Lloyd's Register is a fascinating institution. Not many organisations have managed to inspire their people with the kind of loyalty and devotion to duty that kept the Society going—and growing—for over two centuries.

It is my firm belief that these human qualities will never lose their decisive influence upon the fortunes of Lloyd's Register.

Our mission will be to create a commercially keen organisation, whilst preserving an atmosphere in which these human qualities can continue to flourish. This is no mean task, but it holds the kind of challenge which cannot but appeal to people who look to their jobs to give them something more than mere material compensation for their efforts.

I believe that in the Staff Association we have an instrument which could contribute substantially towards achieving this aim.

More people from various departments in all parts of the world could be encouraged to communicate to their colleagues what they believe might be of use to at least some of them.

The discussions following upon these contributions would enable some to resolve their own—similar—problems, others to see these in a better perspective.

Of course, it would not be practicable for all of such contributions to be presented personally at a Staff Association Meeting, but this should not mean that valuable information or advice should be withheld from people who might be in need of it.

Nor do I wish to suggest that each contribution should be of sufficient length and content to warrant a separate paper. There might be a case for Staff Association Papers containing a number of contributions at a time, relating to roughly the same subjects.

I am aware that an extension of the task of the Staff Association's Committee in its present form to carry out the kind of exercise I have outlined would be a physical impossibility, but I am sure that this problem could be overcome.

In this paper I have tried to make up a rough balance of our assets, coming to the conclusion that the future of Lloyd's Register is assured, providing we succeed in completing the organisational rebirth as planned and currently being implemented.

I also emphasized—I hope superfluously—the essential condition that we do not forget to provide seat belts for the whole of our staff, lest some be thrown out of the Lloyd's Register express as it gathers momentum.

With this is mind, the fundamental thought behind my sug gestions has been aimed at preserving and possibly strengthening the lines of communication between people working in different places and under different circumstances, but all forming an essential part of that intriguing body of men and women that is Lloyd's Register of Shipping.

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*Lloyd's Register Staff Association*

Discussion

on

Messrs. J. B. Davies, D. Gray, E. W. Venner and J. G. F. Warris's Paper

# LLOYD'S REGISTER STAFF ASSOCIATION: THE PAST AND THE FUTURE

Paper No. 1. Session 1970-71

*The authors of this paper retain the right of subsequent publication, subject to the sanction of the Committee of Lloyd's Register of Shipping. Any opinions expressed and statements made in this paper and in the subsequent discussion are those of the individuals.*

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## Discussion on Messrs. J. B. Davies, D. Gray, E. W. Venner and J. G. F. Warris's Paper

# LLOYD'S REGISTER STAFF ASSOCIATION: THE PAST AND THE FUTURE

MR. B. HILDREW

I would take issue with the historical note in that I consider that Fig. 1 represents a decline in attendance if one relates it to the staff increase at H.Q. over the past decade. It is undoubtedly an improvement on the year 1956 when I had the privilege of giving a paper to the Chairman, the Secretary and three Surveyors. Needless to say it was a very short presentation and discussion. I consoled myself then and I am convinced now that attendance is not fundamental to a Staff Association paper as it is read and digested by Surveyors at all outports and in the past has provided a positive up-dating in the service which the technical staff is able to give to our clients. This has undoubtedly been so over the past 50 years.

With this paper we achieve two notable firsts: to start with it is a safe bet that we have never had the word "incunabula" in our transactions before, and secondly, apart from looking back, there is an indication by all Authors that they consider the pattern of the Association must change in the future primarily because the Society itself is changing as new technologies impinge upon our fields of work.

Despite the sometimes divergent views expressed by the Authors there is a common interest which all members of staff share and that is to see that the Society and its work flourishes and grows. This common interest is related to all facets of our work both technical and administrative, and the inclusion in recent transactions of papers on how we are organised and staffed is an indication of this growing unification of interests. Such papers have a wider interest than the purely technical one and thus, contrary to Mr. Davies' views, it might be considered that L.R.S.A. is more aptly named "as is" at this point in time.

It must be apparent to all of us that our pattern of work is changing and must change as technology advances. It is essential in the specialist subjects that information is circulated to the field surveyors by those members of staff who are closely associated with the subject. I am not too clear on the the reason for the emphasis by Mr. Gray on work on such papers being carried out and paid for during working hours. Surely, in the main, a lot of the content of a paper evolves during working hours and we are paid during such time. I would prefer that papers be produced because of the interest an Author has in his subject rather than the need to earn additional cash. There is no doubt that the response of our Outport colleagues to the Authors of technical papers relating to our work is one of high regard. As an example Simpson on Load Line is an invaluable working document to our colleagues in the field and is universally recognised as such. There is great effort involved in producing such a paper but the personal satisfaction and the knowledge of the high esteem in which it is held is of greater personal value as a human relationship between colleagues than some overtime rate negotiated in order to maintain paper fodder for our transactions. I would agree that there is scope for papers by departmental heads and heads of outports as well as papers on specialist subjects. We would all wish to see more papers from outport colleagues. Two problems are here involved: —

1. Locating the Surveyor with the experience and knowledge, and
2. persuading him of the value of imparting such knowledge.

I have no doubt that the most difficult problem to solve is the former.

I am not convinced that there would be any need or value in papers on general shipping matters. Perhaps Mr. Gray could more clearly define what he has specifically in mind in this context.

Mr. Venner's contribution is essentially an examination of the potential staff pattern of the future and the necessary training in management skills as well as technical skills which are becoming increasingly essential in the engineering field. His comments relating to the Professional Engineer Manpower Survey are particularly relevant. A high proportion of engineers move into the management field as they mature (grow older to be more accurate). Many of us are very loth to leave behind the close contact we have with shop floor engineering and we are fortunate in Lloyd's Register that our function enables us to maintain technical contact. However, we can only do this if we keep pace with technological advance. This, I regret, is where some of our colleagues fall down.

Mr. Warris also devotes his assessment to the future and indicates the necessity of the Society to continue to grow within the context of its present pattern of work. This pattern of work is related to the increasing variety of equipment operating on, over and under the sea, as well as industrial plant on land.

Considerable thought is being given to diversification and the attempt to establish a co-ordinated specification service is representative of one facet of potential development. The changing pattern of quality control will also have its impact upon our methods of work and we must in certain areas adjust our pattern of survey to the new production techniques now common in industry.

The changes in our staffing structure and the increasing number of positions and responsibility within the Society are indicative of the developing scope of our work and the increased potential for the fully equipped of our staff to develop their capabilities further. In the immediate future every opportunity must be taken to develop the Society's services in new fields and the potential for technical and administrative staff should continue to grow. It is desirable that there should be a growing together of the two sides of the organisation and one would hope the Staff Association would provide a focal point and a common interest to us all in the foreseeable future.

Thus I would suggest that the Staff Association might consider widening the terms of the Association thus providing a wider scope for papers. It could, with advantage, use as a target the desirability of one paper per annum from our divergent technical bodies, i.e. Industrial Services, Specification, Quality Control, Computer. Additional papers dealing with Port Management, Staff Training, as examples, could with advantage be given.

One final comment with reference to the external paper: it is hoped that the provision of an annual paper by an Author external to our Society will continue. Every effort should be made to make this a major event and we should extend to the Authors the courtesy of a high attendance on such occasions.

MR. S. N. CLAYTON (Hamburg)

Having been born in the same year as the Staff Association adds to the pleasure I have in paying tribute to the Association on the occasion of its 50th Anniversary and to congratulate the Authors on their combined paper.

Some of the Authors have concentrated on the future of the Society itself and in certain parts I felt that we were having a continuation of the late Mr. Knowles' paper. This is understandable since the future of the Association is indeed bound up with that of the Society itself. However, for myself I will confine my comments to the Staff Association.

The Authors have referred to the valuable papers presented to the Association during the past years and as an Outport Surveyor I would re-echo these thoughts. On many occasions I have found that the Rules, Circulars, Instructions to Surveyors and the Secretary's letters, have not answered my problems but I have very often found guidance in the Staff Association papers: "Steel Testing", "Chain Cables", "Safety Equipment" are only a few examples of the many which have been of assistance.

If we consider the Rules, Circulars, etc., as the official media then the Staff Association publications are the unofficial media, but in this lies the strength of the Association. An open forum is provided for discussions and an exchange of ideas which in turn adds to the value of the individual papers. There would, to my mind, be an advantage in also bringing the Technical Journal and Technical Bulletin under the auspices of the Staff Association. This particular type of information would then be available from one source, preferably using the same format for all the papers since our bookshelves at present contain publications in too large a variety of sizes.

Having regard to the world-wide location of staff, Headquarters must remain the centre for the Association, but I suggest that the Staff Association Committee should consider more direct links with staff of other than British nationality. The list of names given in the Syllabus each session gives little impression of an international organisation whereas, in fact, other nationalities form a large proportion of the staff. It would, obviously, be too costly to expect representatives from all parts of the world to attend meetings in London, but we could have "Correspondents" in the larger countries or areas. These need not be senior staff but preferably younger, enthusiastic Surveyors and nationals of the countries concerned. This would, I believe, bring about an increased interest and participation in the Association's activities and further add to the already great value of its Transactions.

MR. W. A. COOK

**INTRODUCTION**

Mr. Chairman, my Authors, Ladies and Gentlemen.

When I accepted the invitation of your President to participate in the discussion on the paper which has been presented to you this evening, I had no idea of its contents as copies of the paper had not been distributed at the time. However, the title appeared most attractive and the occasion timely on the eve of the 50th Anniversary Celebrations of this renowned Association.

The paper contains much of interest to all concerned with the welfare and prosperity of the Staff Association, but I must express surprise that so much space has been allocated to telling us what the future of the Society may be in years to come.

Whilst what is written is most interesting and informative I would have thought that such a descriptive forecast would constitute the subject of a separate paper.

It is a well known saying that we cannot judge a book by its cover, and on this occasion we cannot exactly match up the title of this paper with its contents.

I do, however, agree with the Authors that there is but little object in speculating about the future of the Staff Association without endeavouring to form some idea of the future of the Society and in this context two of the Authors have ably expounded their views.

We must not, however, be led into thinking that the functioning of the Society would be impaired if no Technical Papers were read. The Staff throughout this international organisation, however, would be all that amount worse off if we did not have colleagues who, for long periods of time, devote a considerable number of their leisure hours in compiling a paper for reading before this Staff Association.

For this we must be grateful.

Now, can we forecast what is the future of this Staff Association, and can it exist on its present arrangements of encouraging staff to prepare papers, whether they be of a technical nature or otherwise?

With the evolution of change which has swept through the Society in only the past few years and with the introduction of the computer, which has yet, so far as I am concerned, to prove its worth, the load on the staff in Outports has considerably increased and I feel that this view will be shared by Headquarters Staff.

I would not agree with one of the Authors who propose that our Association be divided into two completely separate bodies, the present name being retained and a new body be known as Lloyd's Register Technical Association.

In this day and age when we are endeavouring to apply Inter-Departmental Flexibility we should consider changes in the Rules of this Association and incorporate in them the non-technical body of the Society.

We should convert them into thinking technical just as they have converted us into thinking clerical.

The odd hour or so a Surveyor could once upon a time squeeze out of his working day in order to jot down a few notes in preparation for compiling a paper has disappeared.

The technical know-how which the average Outport Surveyor could once upon a time impart to the Society's client is also disappearing because the Surveyor is being gradually wrapped up in this terrific paper explosion which has hit all of us.

This, combined with the demands upon the Outport Surveyor to make an all-out effort to meet the daily financial target figure expected from him leaves but little or no time to train his thoughts into compiling a contribution in the form of a paper to be read before this Association.

How then are we to expect the Outport Surveyors (and I can only speak on their behalf this evening) to make a contribution to this admirable cause around which this Staff Association is built?

In order that the Society may show its further appreciation of the efforts made by the Committee and Authors of papers and fully exploit the value which may be derived from their presentation and ensuing discussion, I would propose that consideration be given to a symposium of two or three days annually, to which members of the U.K. staff and near Continent would be invited.

I do not think that Lloyd's Register would grind to a halt during this period—to the contrary the Society and its staff would be all the better for it.

In one sweep the total number of papers prepared for the Session could be read and discussed and thereafter the papers could be launched to the Outport Surveyors throughout the world where, in principal ports, the papers could again be presented either by the Author or a chosen member of the local staff.

If such an arrangement was agreed, then Authors would be assured of addressing a congregation of an appreciable size and this could build up encouragement within the framework of the Association.

By such means the Association would grow from strength to strength. We would receive a far greater number of contributions to the discussions and in such a wide field we could gather the thoughts of a large cross-section of the Society's staff based in all corners of the globe.

In its present setting we rely on the support of the staff in the London area and I well remember the efforts of a senior member of London Outport staff in making his best endeavours, before the reading of a paper, to drum up interest in the local staff to swell the congregation on the day of the meeting.

With the best endeavours in the world it is practically impossible to read and participate, even if only in a small way, in all papers presented because there is so much other technical literature one is expected to interest oneself in these days.

As mentioned by one of the Authors the reprints of some of the Technical Papers which the Committee have sanctioned for circulating outside the Society have been gratefully received by the Industry at large, not because they are seeking to ascertain the innermost thoughts of the Society's Surveyors and work on those thoughts (like those of Mao Tse Tung), but because it gives the Industry food for thought, and from this is derived the good of all concerned.

The Staff Association has had remarkable achievement and most of the papers which have been presented have, in my opinion, formed an invaluable work of reference.

In ports abroad which are still out of reach of easy communications with London or the central office of the country concerned, the Surveyors have relied, for guidance purposes, on many a Staff Association Paper and this is where the value of these papers is felt the most.

We in the Society's field force have been guided through many a difficult assignment by the information contained in papers, as they are in general the work of practical or technical men setting forth in print their knowledge and experience. This, combined with members' contributions to the discussions, has been most informative to the Outport Surveyor.

It would appear that the strides this Society is making into the future and the feed-back of technical information which will be required by Headquarters to satisfy the hunger of the departments and their side kick, the computer, will reduce the amount of free time for the Surveyor in the field, if he ever had any free time, and thus, whilst many would be only too willing to contribute a paper, very few have the time to spare to compile one.

## CONCLUSION

In concluding my remarks may I suggest that in order to assist those Surveyors who would be Authors and have the knowledge to write a paper, but are confronted by the inability to express their views in a manner which would hold the interest of a congregation of colleagues, assistance should be afforded by a panel of more experienced members of the Association in order to relieve the would-be Author of laboriously arranging the text into a presentable composition.

Thank you Mr. Chairman, Authors, Ladies and Gentlemen for your kind attention.

### Mr. A. C. R. CHOUDHURY

Mr. Chairman, the Authors, Ladies and Gentlemen.

The few remarks I wish to make are, if I may say so, from a relatively junior member of the Staff Association. I come from a country with a completely different social and cultural background from that of the U.K., but nevertheless it is not difficult to feel at home in an international Society such as ours whose functions extend to all parts of the world. Our Society in my opinion, can be considered as a big family, whose staff through this Association assist and share knowledge with each other. One of the objects of the Association, initiated as long ago as 1920, is "the spreading of technical knowledge" and anyone joining the Society soon knows this to be true, as each and everyone of his colleagues takes a sincere interest in guiding and teaching him from the day he joins.

Today people are thinking in terms of one world. Naturally, in these changed circumstances, there will require also to be changes in the procedure involved in making decisions in the shipbuilding and other industries. I agree with Mr. Venner when he states that the "one-way traffic in British personnel is no longer sufficient". There should be collaboration and movement in many directions. In what way can this be best effected? Should we not think in terms of special training to assist Surveyors in adapting themselves to varying cultural conditions in different countries?

In a paper written for this Association in 1947, Mr. Colin Bartlett, the then Personnel Manager, wrote: "Good Surveyors are not only highly qualified technically, but, by their personality and tact, act as Ambassadors for the Society they represent". For personnel working in countries other than their own, such tact and a determination to be accepted is even more important today when there as so many newly independent countries. Our Society has a distinct advantage here because of its international spirit and its fellow feeling.

Due to technological advancement within the Industry I also agree with others that it is now more difficult for members of the Association to continue to write worthwhile papers in their own time. Perhaps ways can be found for making opportunities available to the staff for this kind of work to be continued in the high quality vein to which our Association has become accustomed.

Finally, one point in connection with the technical papers written for the Association. Is there any reason why they cannot all be made generally available to the industry rather than be limited to circulation for the benefit of the staff only? It is realised that such papers are expressing the opinions of the Authors and not those of the Society itself but this difficulty could surely be overcome by a system of vetting as is done in the case of Technical Reprints which are made of certain selected papers for general issue. Other classification Societies, such as the American Bureau of Shipping, circulate their papers much more widely and are, therefore, read in many

more different quarters than those prepared by this Association.

As regards the future of the Association, many interesting things have been said in the four articles by Mr. Davies, Mr. Gray, Mr. Venner and Mr. Warris, to whom our sincere thanks are due. I would like to add that the future of the staff and indeed of the Society itself will be assured if we sincerely continue to work towards our aim of "facilitating co-operation among countries".

## WRITTEN CONTRIBUTIONS

### Mr. L. D. TRENCHARD (Glasgow)

This is European Conservation Year. ECY has two principal and explicit aims: —

> To agree on policies which will help to conserve and improve the quality of our environment and to find the best ways to put them into action: to make conservation problems clearer to everyone, so that there will be better support for any measures needed to deal with them.

I think that this could be said to apply to the Lloyd's Register Staff Association at this present time. Not that the technological explosion, to which the Duke of Edinburgh has referred, has littered the Society with immense technical complexes, but there is the need to create an administrative system which is capable of formulating a sensible and comprehensive policy which can take the right decisions and eventually carry the policy and decisions into effect.

I congratulate the four Authors upon the deep thought which they have given to the subject, although Mr. Venner and Mr. Warris in their contributions have concentrated upon the Past and the Future of Lloyd's Register rather than of the Staff Association. Their reasoning is very sound. Mr. Warris appreciates the value of Staff Association Papers to the man in the field as an instrument which could contribute substantially towards creating a commercially keen organisation whilst preserving an atmosphere in which the human qualities of loyalty and devotion to duty to the Society can continue to flourish. This I applaud, but the terms of reference of the Staff Association must be amended to permit this and the suggestions of Mr. Davies and Mr. Gray. I agree with the relevant part of Mr. Davies' contribution but, of course, I cannot agree with the limiting effect of the title "Technical Association". The boundaries must exceed this as Mr. Davies, himself, agrees.

I agree to the full with Mr. Gray's contribution and particularly with his views for the future.

I would say that we have read of the Past of the Staff Association in the many papers we have in our possession and which we can borrow. It has provided a valuable service, and my copies of Heck, Porter, Dorey and Pemberton are almost beyond repair. But now we have to plan for the future, as I stated in my opening remarks. Not because 50 years signify change, but, perhaps, because the promotion of this very paper has high-lighted the fact that we must look to the future and make a change which will fit in with the changes, the great changes, which are now taking place within the Society. The "technological explosion" has overtaken the present Constituency of the Staff Association as a means of carrying information to the whole of the Society's Staff.

Our thanks are due to the present and past Committees of the Staff Association and to the untiring Secretaries who must have burned much midnight oil, and to the many contributors.

The time has come to merge the Staff Association with the Training Scheme to create an administrative system for the planning and rigid control of technical and administrative information. Mr. Stoot has already made a start by circulating the "Journal" and this must be developed. The Headquarters staff are fully aware of the rapid developments which are taking place and which affect the Surveyors at all the ports. The Training Department should be extended to contain this administrative system because, after all, Staff Association Papers are most definitely part of a training scheme—the transmitting of knowledge of a specialist kind. Certain Surveyors should be allowed time to develop papers, on a controlled basis, which should be distributed to the ports for written discussion within a defined time and taken to Regional Centres—say four in the United Kingdom—for discussion and also to the principal ports overseas. The discussions, written and verbal, must be studied and, if necessary, the original paper amended for final issue in the Journal as a "Guidance Document". These documents must be kept up-to-date by the issue of amendments or, ultimately, withdrawn. In addition to this the Journal should contain contributions from specialists outside the Society, whose particular sphere of activity runs parallel with, and is complementary to, that of the Surveyors.

The Journal must be issued to a rigid timetable three or four times a year. While not every issue may contain a "Regionalised" paper, Surveyors should be encouraged to make contributions. Papers must be circulated in adequate time for study before the paper is read, or discussed, and more than the 24 hours which the issue of this most interesting paper has allowed.

### Mr. J. R. G. SMITH

I would like to thank the co-Authors of this paper for providing us with much food for thought, and stimulus for discussion.

In my opinion the main object of this particular Staff (or, as Mr. Davies suggests, Technical) Association must always remain the advancement and dissemination of knowledge in shipbuilding, marine engineering and other matters of technical interest. Each individual Surveyor to Lloyd's Register of Shipping accumulates a vast amount of technical knowledge and experience throughout his career, and this Association is at present the only available means of disseminating this individual expertise for the benefit of all. From time to time members of the Clerical Staff should be invited to read papers of particular interest in accordance with present practice, and there should be an open house at all meetings. There should, however, be no deviation from the main object of the Association as now defined.

Regarding Mr. Davies' thoughts on a second Association having a much wider range of activity, I feel this is bound to come eventually. I would point out the obvious, however, by stating that there are still many advantages to be found in the existing informal system. In forming the kind of Staff Association Mr. Davies has in mind we must be very careful to preserve these advantages.

### Mr. B. K. BATTEN

I feel I must begin on a note of apology to the Authors for, on first reading this paper, I felt disappointed that, with one exception, they had stepped outside their brief; and it was not until I began to resolve my own thoughts that I realised how closely the future of the Staff Association and of the Society are linked together.

Mr. Warris hit the "marketing" nail firmly on the head when he wrote "the Society is in business to sell Surveyor-hours", and if this involves greater diversification of our services, then we must be ready and trained to meet this *before* the need arises. Mr. Warris has also reminded us of the external threats to the Society's interests, threats which may bring us into a closer relationship with present rival Societies. More vitally, he has warned us of the internal dangers of complacency, parochialism, and lack of dedication and a sense of urgency. I rather wish he had also managed to spell out a list of our own shortcomings.

What part has the Staff Association to play in this future? I think three-fold as an *informal* (not unofficial) vehicle of communication.

(1) I agree with Mr. Gray that Outports have the right to know what is happening in London, particularly in relation to the function and output of departments who currently hide their true nature behind a façade of bewildering initials. Those who have visited a large number of Outports, particularly overseas, *must* have humbly sensed the measure of awe and respect held for Head Office, and I am sure that free and frank communication can only serve to strengthen this respect.

(2) The Staff Association has a function to rationalise and simplify the obscurities which are bound to creep into our Rules and Instructions. Several past papers of this type have already been cited, some of which have been of inestimable value to the man in the field faced with explaining the subtleties of "in this instance may be, should be, could be," etc. Where there is insufficient material for a single paper I should like to see a forum where five or six "notes" prepared, perhaps as a departmental function, could be discussed in and out of London and subsequently circulated.

(3) The Staff Association has a responsibility to disseminate knowledge, and this, I must add, in a readable manner. We are not, frankly, a learned association as such, nor should we seek to emulate them, or to couch our facts in erudite phraseology. Let our writing be short, simple, and crystal clear—or it won't be read.

Finally, the future of the Staff Association, and of the Society depends on you and I. I have always proudly maintained, though perhaps noisily, the the Society's staff were, not a union, but a family of independent and dedicated men. If we are to hold our place at the forefront of classification we must not be content to remain as we are, so that we are not only *said* to be but *seen* to be more alive and more knowledgeable and better prepared than the "firm-next-door".

A very very sobering thought from Holy Scripture brings us a fitting challenge for our time.

"Whatsoever thy hand findeth to do, do it with thy might, for there is no work, nor device, nor knowledge, nor wisdom in the grave whither thou goest."

## AUTHORS' REPLIES

### By Mr. J. B. Davies

Since the original paper comprised the opinions of four individual Authors and the discussion was once again individuals' opinions, it is extremely difficult for the Author to reply.

There are, however, two major points on which I think I might comment. The first is the suggestion made by several contributors that the Staff Association should broaden its scope to take in items such as the Technical Journal and the Technical Bulletin. To my mind this would be a bad move since the whole virtue of the Staff Association is that it is entirely unofficial whereas the Bulletin and the Journal must be considered as at least semi-official (this was a point made by one of the contributors to the discussion who, unfortunately, does not appear to have put his views in writing).

There would appear to be a slight misunderstanding regarding my suggestion that the present Staff Association should be renamed and a new Staff Association might be formed for personnel matters. I was not advocating this at the moment, but we were asked to consider the future of the Staff Association and I am quite convinced that within the next 50 years the changing climate in which we live will lead to a demand for an Association to deal with the latter matters.

### By Mr. D. Gray

Mr. Hildrew had questioned the necessity for Staff Association Papers to be written during working hours. In Mr. Gray's opinion the conditions of modern living are now such that it is extremely difficult for a man to write such papers outside office time and that these difficulties will become more pronounced in the future. The point of view put forward by Mr. Gray would appear to be supported by Mr. Cook, Mr. Trenchard and Mr. Choudhury in their contributions.

There was no suggestion in the mind of Mr. Gray that a man who wrote such a paper should receive "additional cash" over and above his salary. The reference to such a paper being "paid for", when written during office hours, merely referred to the fact that if a man were allowed a certain number of hours per week to prepare and write a Staff Association Paper, then the man's normal work during those hours would not be carried out by him. Thus the Society would lose a certain number of man-hours per week, whilst the paper was being prepared, and this represents a cost to the Society. Mr. Gray had merely wished to point out that if papers are to be prepared and written during normal office hours the Society must be prepared to pay the cost.

The reference to papers on general shipping matters: There is now such interpenetration of technological disciplines that it is almost impossible for a technologist to be a competent practitioner in his own discipline without having an awareness of other disciplines and this includes economics. This would appear to be supported by Mr. Batten when he writes ". . . we are not only *said* to be but *seen* to be more alive and more knowledgeable and better prepared than the 'firm next door'."

Mr. Gray was not terribly enthusiastic about Mr. Cook's suggestion for a two- or three-day symposium to be held each year. In Mr. Gray's experience of symposia, such as these, discussion was apt to be rather limited and restricted; certainly less lively than the discussion for a single paper. The reasons are probably that there are too many papers for them to be read in depth (unless the load is deliberately shared among selected members of the audience) and frequently the limited amount of time which can be allocated to each paper and subsequent discussion.

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*Lloyd's Register Staff Association*

# MODEL STRUCTURAL TESTING TECHNIQUES

A. C. Wordsworth

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Hon. Sec. T. Swiatecki
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# MODEL STRUCTURAL TESTING TECHNIQUES

By A. C. WORDSWORTH

## INTRODUCTION

The analysis of a complex structure, for example a ship or aircraft, represents a considerable mathematical effort. In recent years the techniques of structural analysis commonly called the finite element methods have been developed, orientated towards the application of digital computers. However, despite these advances, many problems are too complex, or simply too large to make such analysis procedures economic.

In such circumstances structural testing, which consists of building the actual structure, applying the relevant loading conditions and measuring the resultant stresses, deflections, ultimate loads, etc., provides a method of obtaining accurate data, the only inaccuracies being due to differences between nominally identical test specimen and prototype structure, and to errors in the applied load, deflection, and strain measurements. Such a procedure is expensive, cost increasing rapidly with size of structure. In the case of automobile body design, for example, where a large production is anticipated and the cost of a structural test can be spread over the whole production run, or in the case of an airframe structure where the penalty of excess structural weight cannot be tolerated, the very reliable information which can be obtained from structural testing can justify the high cost of full scale tests.

Consider now the structural design of a large component which will only be produced in small quantities, a ship hull structure for example. Refinements in the design are desirable in the interests of cost savings arising from possible reductions in the amount of structural steel used and the avoidance of embarrassing but non-catastrophic structural failures. It is unlikely that such refinements could justify the cost of building and testing a full-sized test hull, although it is sometimes practicable to test individual details such as corner brackets at full scale, if suitable test facilities are available. However, testing a small scale model hull drastically reduces the cost of structural testing, provided that the loss in accuracy consequent upon the scale reduction is acceptable.

If the model could be made a perfect scale reproduction of the prototype in all respects, then it would reproduce perfectly the behaviour of the prototype, and the following relationship would be valid: —

$$f_p = f_m \left(\frac{Wp}{Wm}\right) \left(\frac{lm}{lp}\right)^2 \qquad \text{——————} \quad 1$$

$$\epsilon_p = \epsilon_m \left(\frac{Wp}{Wm}\right) \left(\frac{lm}{lp}\right)^2 \left(\frac{Em}{Ep}\right) \qquad \text{——————} \quad 2$$

$$\delta_p = \delta_m \left(\frac{Wp}{Wm}\right) \left(\frac{lm}{lp}\right) \left(\frac{Em}{Ep}\right) \qquad \text{——————} \quad 3$$

Where f = stress at any particular point in the structure.

W = a particular load.

l = a particular linear dimension.

$\varepsilon$ = a strain at any particular point.

$\delta$ = a deflection at any particular point.

E = Young's Modulus of the material.

Suffix p = prototype m = model

The stresses, strains and deflections of the prototype could thus be obtained from the measurements made on the model, provided that the ratio between the loads applied to the model and prototype, the linear scale factor, and the ratio of the Young's Modulus for the material of the prototype to that of the model (if different) are known. Unfortunately a perfect scale model is usually impractical, and it is necessary to compromise by simplifying the model and accepting some reduction in accuracy of results in order to reduce the cost of the test.

The object of this report is to describe techniques of testing model structures so that the advantages and limitations of model testing as a design tool become apparent.

Model materials, loading and measuring methods, and a few examples of model investigations are described.

## MATERIALS

Ideally, the model should be made from the same material as the prototype. However, it is often possible to choose an alternative material which will facilitate the construction and testing of the model while still behaving in an acceptably similar manner to the prototype material. Before commencing on the construction of a structural model, it is necessary to choose a suitable model material.

### Steel

Ship hull structures are built of steel. The major problem in producing small scale steel models of steel plate structures arises from the difficulty in joining the thin model plates so as to achieve sufficient strength without excessive distortions of material; for example

(a) Reduxed or soft soldered joints give low distortions but insufficient strength.

(b) Lap joints made using an argon shielded spot welding method with spot welds at 0·2″ pitch give barely acceptable distortions on 0·03″ steel, and rather low strength.

(c) Dip transfer, gas shielded electrode welding gives sufficient strength, and with skilled operators can give acceptable distortions on 0·15″ plate or thicker.

(d) Electron beam welding gives acceptable distortions and strength on thin plates, but is restricted to components which can be accommodated in a vacuum chamber. Few firms have this expensive equipment.

Of all the above methods of joining thin steel plate for models, the dip transfer welding method appears to be the most practicable at present, but even then, if distortions are to be kept low, a minimum plate thickness of about 0·15″ is desirable. This means that for a ship hull or hull detail, the smallest model scale which can be used is about 1/5. Testing a model at this scale still involves very high loads with expensive hydraulic loading equipment and loading frame. Also, to embark upon the manufacturing of these welded models, it is necessary to train a welder in the technique, and to keep him in practice.

### Plastics

An alternative to making the models in sheet steel is to use a plastic as the model material. Plastic scale models will

reproduce the behaviour of steel prototypes within the elastic range, the only inherent inaccuracy within this range being due to the difference of Poisson's ratios between steel (0·3) and most plastics (approximately 0·37). Clutterbuck[1] shows that the discrepancies due to this difference are usually small.

The major drawback of a plastic model is its complete inability to reproduce the plastic behaviour of a steel prototype when stressed above its elastic limit. This is because for most plastics stress is proportional to strain almost up to the point of failure, whereas steel has a "limit of proportionality stress", beyond which point stress and strain are no longer proportional. A further drawback is that plastics do not exhibit the fatigue or brittle fracture characteristics of steel, and the effects of these phenomena cannot be investigated directly with plastic models.

Advantages of plastics are as follows. They can be machined and formed much more easily than steel. Glued joints can be satisfactory. but there is a tendency for the shrinkage of the glue on drying to slightly ripple very thin sheets. giving a "starved horse" effect on stringer skin panels. The low Young's Modulus of plastics is advantageous since, for example, a 1/16 scale P.V.C. model of a steel prototype will assume deflections equal to those of the prototype for a load of only 0·1 per cent of the prototype load. The corresponding model strains will then be 16 times greater than those on the prototype, and the stresses four times smaller. Thus a comparatively light loading can impose measurable strains and deflections whilst avoiding high stresses likely to break the model.

Vybak rigid P.V.C. material is a typical sheet plastic modelling material. Its Young's Modulus is approximately $0{\cdot}5 \times 10^6$ lb./sq.in. and it can be obtained in sheets $50'' \times 25''$ in thicknesses from 0·01″ to 0·25″. The thickness is only guaranteed to within 10 per cent, but the selection of closer tolerance sheets from a batch can help to overcome this deficiency.

For solid components such as crankshafts where sheet material is unsuitable, models can be cast in an araldite plastic. To produce the castings, araldite resin and hardener are melted at 130° C and mixed in the ratio 100 to 30 by weight. The mix is then poured into the mould, cured for 24 hours at 110° C and cooled very slowly before removing from the mould. Any machining may then be performed.

### Rubber

As an alternative to araldite, cast silicone rubber models may be used for qualitative tests. The low Young's Modulus of about 300 lb./sq.in. allows large deflections to be produced with very small loads. Modes of deflection may thus be demonstrated visually and household paint used as a strain sensitive coating to indicate areas of high stress. The disadvantages of this material are the deflections due to self weight, the high Poisson's ratio of about 0·5, and the non-linear stress-strain curve which precludes quantitative tests.

### Miscellaneous

Micro-concrete models using suitably graded aggregates with or without steel reinforcing or pre-stressing rods have been used for investigating the behaviour of dams, bridges, shell roofs and other civil engineering structures. In the aircraft industry, flutter models have been manufactured with light alloy skeletons to give the required stiffnesses, and steel weights and foam plastic covering to give the correct mass distribution and aerodynamic shape.

Cardboard is probably the cheapest of all model materials, and cardboard models can yield useful qualitative results.

## MODEL LOADING TECHNIQUES

The design of representative load application points on all models must be considered. St. Venant's principle states that the actual distribution of the forces applied to a small area only affects the magnitude of stresses in the immediate vicinity, and that at distances from this area which are large compared with the area's dimensions, the distribution has negligible effect on the stresses. Thus, if for instance, a model of an engine crankcase is to be used to investigate the overall bending or torsion of the crankcase, the loads representing the crankshaft loads at the main bearings may be applied as resultant point loads at the periphery of each bearing, rather than distributed around the periphery as occurs on the prototype. This will not affect the required overall crankcase behaviour appreciably, but the behaviour of the actual bearing and bearing girder will be unrepresentative. Contact loading conditions at places such as bearings are difficult to simulate accurately.

Fluid pressures may be simulated by sponge rubber pads with back plates, the plates being loaded by a whiffletree arrangement. As an alternative to this, dam models have been loaded with mercury and then whirled in a centrifuge in order to get sufficiently high fluid loads.

It is often advantageous to link all loading points on a model to a single load application point so that loads remain "in step" at all times.

The use of dead load is fraught with danger since any small failure will probably cause the model to be severely damaged. Screw, or hydraulic jack loading is to be preferred as a minor failure will then automatically reduce the load.

### Loading Plastic Models

It is an unfortunate property of most plastics that they creep under load. This creep behaviour can be likened to the spring and dashpot system shown in Fig. 1(a) where a suddenly applied load initially loads both springs, the load from the right hand spring is then transferred gradually to the left hand spring with consequent increase in deflection. The rate of creep decreases with time. Fortunately, the creep characteristics of Vybak and Araldite are such that at a given time after loading, the strain is proportional to the stress. Thus

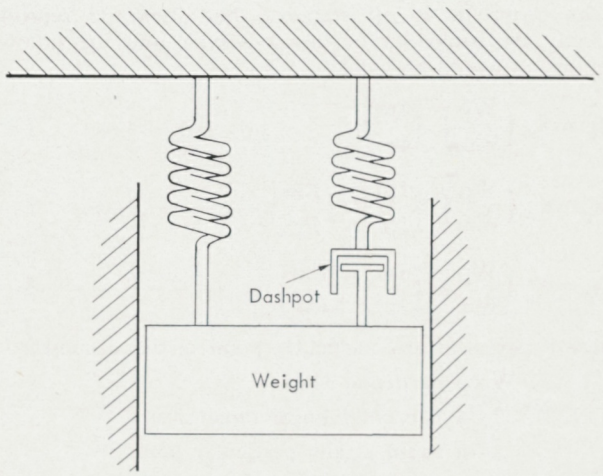
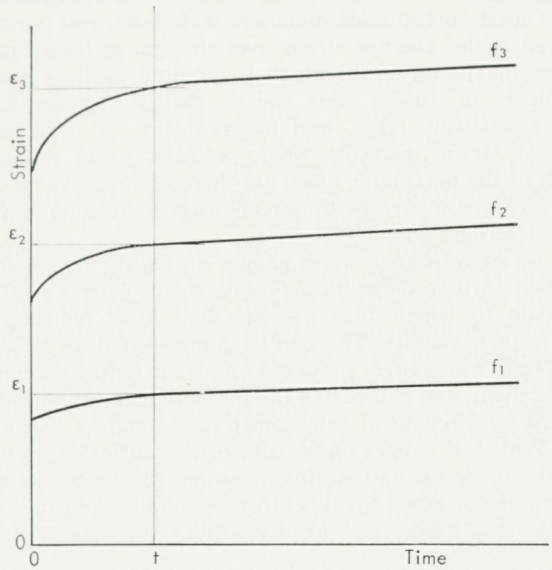



FIG. 1(a)

Creep behaviour analogy.

Young's modulus, $E_t$ may be calculated for any given time t (*see* Fig. 1(b)). If, therefore, a model of such material is subjected to load, then at a certain time t after loading, the stress at any point is related to the strain at that point in the ratio $E_t$.




$$E_t = \frac{f_1}{\varepsilon_1} = \frac{f_2}{\varepsilon_2} = \frac{f_3}{\varepsilon_3}$$

FIG. 1(b)

Instantaneous value of 'E' at time 't' (characteristics shown exaggerated for clarity).

One test procedure, therefore, is to apply a load to the model, then after 15 minutes take the measurements as rapidly as possible, remove the load and wait until the creep deflections have reduced to near zero, then repeat for a higher load, and so on (*see* Fig. 1(c)). In this way a plot of deflection or strain against load for each measuring point may be obtained and related to $E_{15}$. (The ratio of stress v strain 15 minutes after load application.)

Alternatively a compensating plastic ring may be used in series with the loading circuit as shown in Fig. 1(d). Here a deflection $\delta_R$ is applied to the ring, and the resulting deflection $\delta_m$ measured on the model. As creep occurs in both model and ring, the deflections $\delta_m$ and $\delta_R$ remain the same, but the load W relaxes. A plot of $\delta_m$ v $\delta_R$ is made for various values of $\delta_R$. The stiffness of the compensating ring may be calculated for any assumed value of $E_m$, and this stiffness scaled up using equation 3 and the same assumed $E_m$, to give the stiffness of a corresponding ring of prototype scale and material. Then,

$$\text{stiffness of prototype} = \frac{\delta_R}{\delta_m} \times \text{stiffness of scaled up compensating ring.}$$

This method of load application has the advantage that provided that $\delta_m$ and $\delta_R$ are of the same order the effects of creep are nullified, variations of $E_m$ with temperature and humidity are compensated for, and testing can be done quickly.

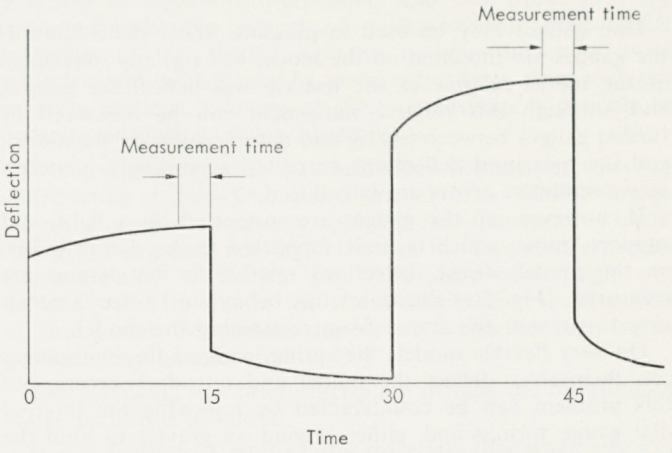



FIG. 1(c)

Elapsed time loading technique (characteristics shown exaggerated for clarity).

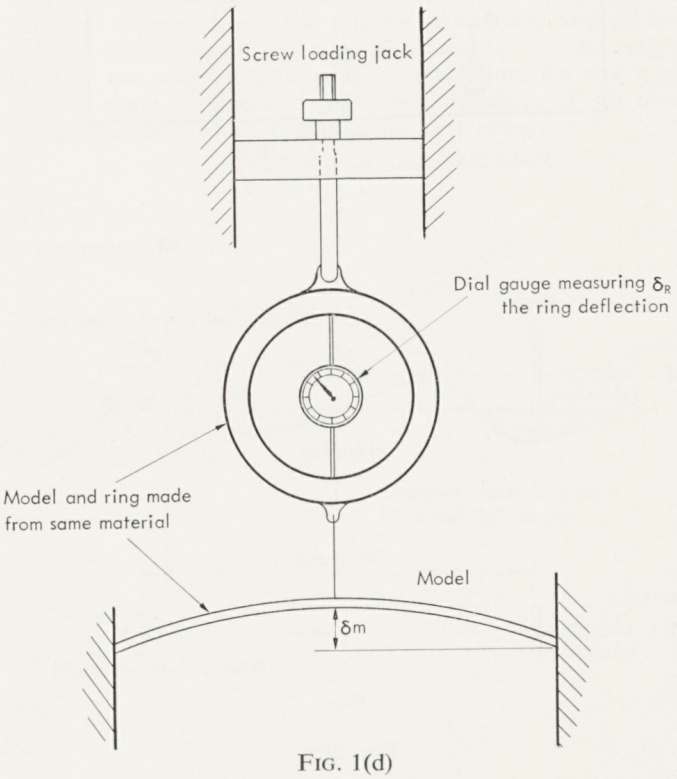



FIG. 1(d)

Compensating ring loading technique.

## MEASUREMENT OF DEFLECTIONS

Dial gauges may be used to measure linear deflections. If the gauges are mounted on the model test rig, any movement of the model relative to the test rig will deflect the gauges, and although this relative movement can be measured by further gauges between test rig and datum points on the model, and the measured deflections corrected accordingly, unnecessary cumulative errors are introduced.

If, however, all the gauges are supported on a light, stiff support frame, which is itself supported at the datum points on the model, direct deflections relative to the datums are measured. (Fig. 2(a) illustrates this behaviour.) Care is necessary to prevent the frame from restraining the model.

On very flexible models the spring loads of the dial gauges can themselves deflect the model and introduce errors, but this problem can be counteracted by removing the internal dial gauge springs and, either relying on gravity to hold the gauge anvils in contact with the model or fitting more flexible springs.

Optical methods of measuring deflections with travelling microscopes or telescopes and scales overcome the problem of spurious loads from the dial gauges, but the measured deflections are relative to the microscope and usually have to be corrected for movement of the model datum points relative to the microscope.

Fig. 2(b) shows a method of measuring angular deflections by an optical method.

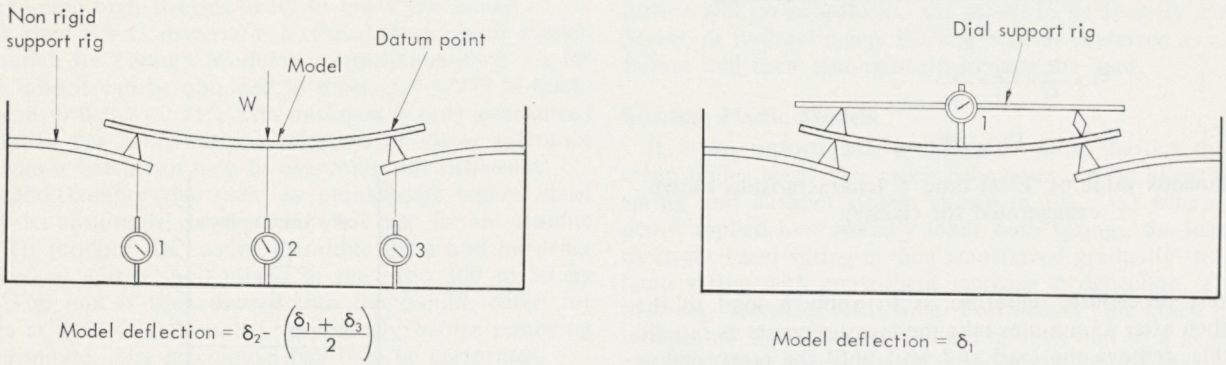



FIG. 2(a)

Measurement of linear deflections.

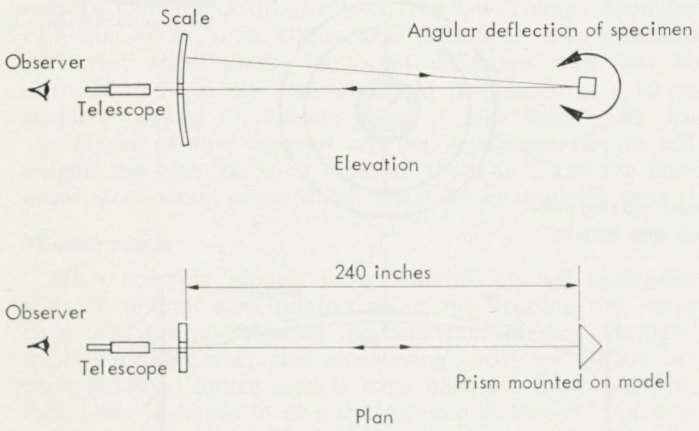



FIG. 2(b)

Measurement of angular deflections.

## MEASUREMENT OF STRAINS

### Resistance Gauges

On full scale structural tests, resistance strain gauges are the usual method of measuring strains, and where strain gradients are low they are satisfactory. However, the smallest strain gauges that can be used have a particular gauge length, whether used on full scale or model scale tests, and the strain measured is the average strain over this gauge length rather than the maximum strain which is required. Scaling down a component for model tests means that the gauge length becomes relatively large, and the problems of using strain gauges at strain gradients where average strain is only a fraction of the maximum strain are therefore aggravated. This problem can be overcome by the photoelastic technique which will be described later.

The use of resistance strain gauges on plastic models introduces two further difficulties. Firstly, strain gauges reinforce the plastic to which they are attached, thus reducing the strains in their vicinity. This can be compensated for by doing control tests with gauges mounted on plastic tensile specimens, straining them, and comparing the measured strains with those measured by mechanical extensometers to obtain a correction factor. With foil gauges on Vybak, discrepancies of up to 26 per cent can occur, and strains measured on the model must therefore be corrected for this error. Secondly, the gauge current heats the model and locally softens the plastic. Errors due to this can only be kept low if a small gauge current is used.

Resistance strain gauges may therefore be used satisfactorily on steel or plastic models provided that the strain gradients are not excessive, and that on plastic models the necessary correction factors and low gauge current are used.

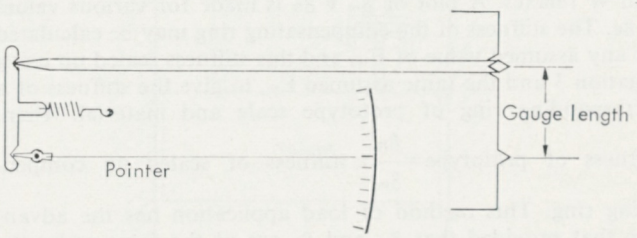



FIG. 2(c)

Mechanical extensometer.

### Mechanical Gauges

Where the model strains are uniform over gauge lengths of 0·5″ or greater, mechanical extensometers can sometimes be used to measure strains. These extensometers consist of a pair of magnifying levers as shown in Fig. 2(c). They are fairly sensitive, strains of 10 $\mu$ strain can be measured, and they can be quick to use provided that a simple method of clamping them to the model is possible.

### Brittle Lacquers

Some brittle lacquers provide a practical means of measuring qualitatively the strains over a large area of the model. The lacquer is sprayed on to the model, several calibration beams being sprayed at the same time. Subsequent sprayings eventually build up a lacquer thickness to about 0·003″ and five hours drying time is then allowed. The model is then loaded in increments, the lacquer being inspected for cracking at each increment and the position where cracks first occur indicates the position of maximum tensile strain, the cracks running normal to this strain. The calibration beams are now loaded until the lacquer cracks, the strain at which this occurs being determined from the beam deflections, which gives a qualitative value of the strain where the lacquer on the model first cracked. The load may now be increased to obtain an overall strain pattern.

It is usual to follow up the qualitative brittle lacquer tests with quantitative strain measurements using resistance strain gauges.

Lithium tetraborate glass, which was developed as a brittle lacquer by the R.A.E., is a suitable lacquer for use on plastics, steel or aluminium. Initial cracks occur at about 700 $\mu$ strain. Its main drawback is that it must be used in a temperature and humidity controlled laboratory.

## PHOTOELASTIC MODELS

Photoelasticity is a method of investigating stresses in models by optical means.

The optical phenomenon upon which this technique relies was first observed in 1816, but it was not until 1912 that any practical investigations were done, and this work was very restricted until the advent of really suitable photoelastic materials in the 1940's. Araldite is now the most usual material, and models may be made either from sheet material or from castings. Glueing of sheet or castings is possible in order to produce complex structures.

The two-dimensional photoelastic technique consists of constructing a two-dimensional model in a suitable transparent photoelastic material, applying the representative loads, and projecting polarized light through it. Interference fringes which are then visible (*see* Fig. 5) in the emergent light can be interpreted to obtain the stress distribution at all points in the model. Maximum stresses at points of high stress gradient may be measured.

The following is a brief description of how the interference fringe pattern is produced.

It is a feature of photoelastic materials that when stress is applied to them and plane polarized light projected through them, then the plane polarized light wave is split into two mutually perpendicular waves on entering the stressed material, the plane of each wave being parallel to one of the principal stresses. Also, the speed of each wave through the material is decreased by an amount proportional to the relevant principal stress. This change of speed alters the relative phase angle between the two emergent waves. The two emerging waves are passed through a further polaroid (the analyser) which is "crossed" with the polarizer, and the component of each wave in the plane of the analyser now emerges. If the final component waves are out of phase (*see* Fig. 3(b)) no light emerges from the analyser. (P–Q) the difference between the principal stresses which produces one wave length relative retardation and thus zero emergent light can be calculated from the material constants. Increasing the principal stresses alters the relative retardation and allows light to emerge again (*see* Fig. 3(a)) until, at stresses which produce two wave lengths relative retardation, the emerging light is again extinguished, the stress difference (P–Q) now being twice that which produced the first extinction.

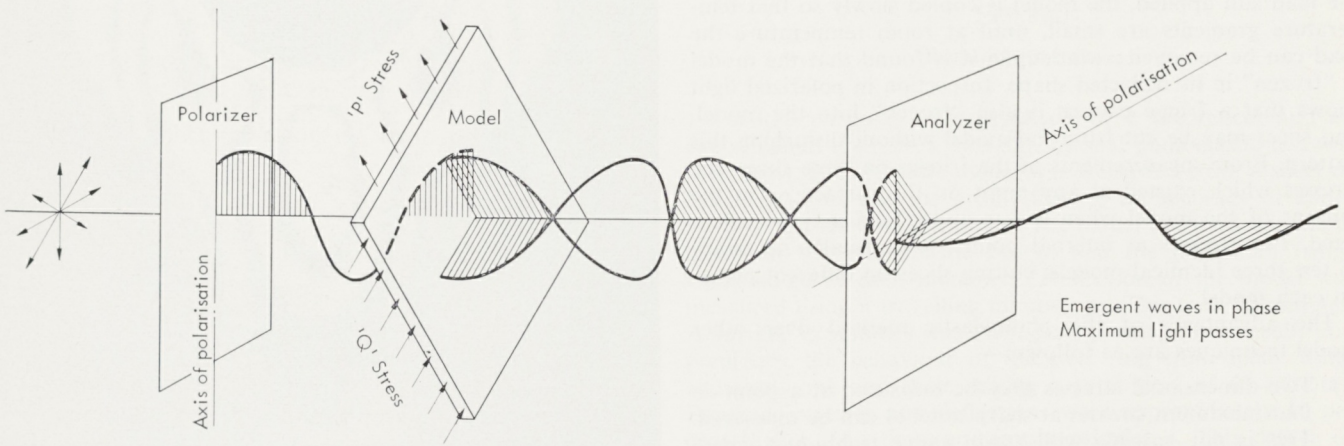



FIG. 3(a)

Light fringe.

Passage of light through a simple polariscope and model.

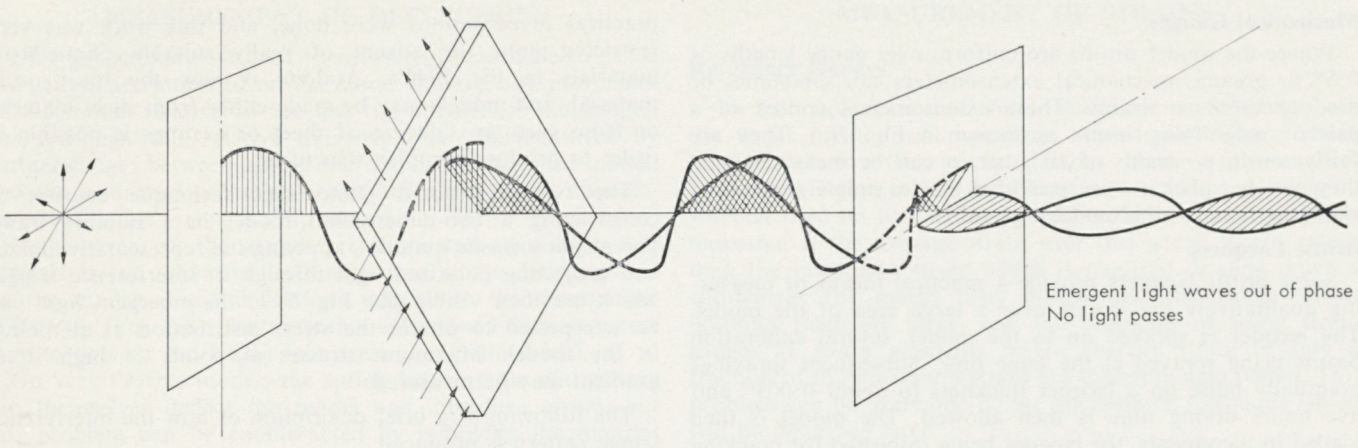



FIG. 3(b)

Dark fringe.

This behaviour is demonstrated mathematically in Appendix 1.

The variations of P–Q throughout the model thus produces a pattern of dark interference fringes, each fringe being designated by N the number of wave lengths relative retardation and joining points of equal stress difference (P–Q). Fig. 5 shows a typical fringe pattern. Positions of high stresses are instantly apparent, and all stresses may be measured quantitatively.

As well as measuring stresses in two-dimensional models, photoelasticity may be used on three-dimensional models. To do this the stresses must be "frozen" into the model as follows. The model and its loading rig are placed in an oven and the required load applied. The oven is heated to 135° C and this temperature is held constant until it is reached throughout the model. At this temperature the model material softens and the model deflects under the applied load. With the load still applied, the model is cooled slowly so that temperature gradients are small, until at room temperature the load can be removed; whereupon it is found that the model is "frozen" in its deflected shape. Inspection in polarized light shows that a fringe pattern is also "frozen" into the model, and slices may be cut from the model without disturbing this pattern. From measurements of the fringes on these slices, the stresses which existed at any point on the surface or in the interior of the model when it was under load may be calculated. For stresses at internal points, it is usually necessary to test three identical models, cutting slices on different planes on each model.

The advantages of the photoelastic method over other model techniques are as follows:—

(1) Two-dimensional stresses may be measured at a point so that maximum stresses at sharp notches can be measured. This is not possible with strain gauge techniques where the average strain over the finite gauge length is obtained.

(2) Positions of high stress are immediately apparent and, on two-dimensional models at any rate, it is unlikely that points of high stress can be overlooked.

(3) Designs may be refined by testing a model, cutting away material at regions of low stress, re-testing and so on, in

FIG. 5

Photo elastic fringe pattern on an araldite eyebolt model.

Fringes join points of constant shear stress $\left(\frac{P-Q}{2}\right)$

order to approach the ideal where the component is uniformly stressed throughout.

Limitations are as follows:—

(i) The technique is not really suitable for investigating ship hull structures which are usually built up into three-dimensional structures from plate. Although the individual plates may be two-dimensional it is unlikely that the two-dimensional technique can be used, because the presence of the adjacent structure prevents the polarized light being projected through individual plates. Also the stresses at joints may vary through the thickness of the plates and therefore be three-dimensional in character. In most cases the three-dimensional technique cannot be used, because the low Young's modulus of araldite at the stress freezing temperature causes buckling of compression plates at stresses so low that no photoelastic measurements can be made.

(ii) The difference between the principal stresses (P–Q) is measured directly. This gives the individual principal stresses at a free boundary where either P or Q is zero, but at a loaded boundary, or an internal point, one of several stress separation methods must be used. These methods involve considerably more work.

(iii) The disadvantages of plastic model testing, such as the inability to simulate plastic strains, still occur.

In addition to the normal two- and three-dimensional photoelastic techniques there are also the "reflection technique" and the "sandwich technique" which are worthy of mention.

**Reflection Technique**

The reflection technique involves using a piece of photoelastically sensitive material attached to a component, instead of a multitude of strain gauges, when investigating stresses over a large area of the component.

The area of the component under investigation is polished to a reflecting finish and a photoelastic coating either painted on to it or glued on as a sheet. Thus, when the component is strained the coating is strained with it. Polarized light which is projected through the strained coating reflects off the component and re-passes through the coating before emerging. On viewing the emergent light through an analyser, a fringe pattern is seen which represents the shear stress $\frac{(P-Q)}{2}$ and the principal strain directions in the coating, and in the component. Areas of high stress are therefore immediately apparent. Separation of principal stresses P and Q at any point can be obtained either by further photoelastic measurements or by strain gauges aligned with the principal stress directions which have been shown by the fringe pattern.

The reflection technique therefore has similar applications to the brittle lacquer technique. It is applicable to model or full-sized structures.

**Sandwich Technique**

One drawback of the stress freezing technique for three-dimensional models is that the model is destroyed when it is sliced, so that a new model has to be made for each loading case. This limitation can be overcome by the "sandwich technique" where a model is made in a transparent material with zero photoelastic sensitivity, but with a slice of sensitive material embedded in it on a plane on which stresses are to be measured. When the model is loaded, it behaves mechanically as a homogeneous component, but polarized light projected through it is affected by the photoelastic layer only, and the resulting fringe pattern represents the stresses in this layer. The problem is to decide which plane to place the layer in.

## EXAMPLES OF MODEL TESTING

A few model investigations which have been done with varying degrees of success will now be described, in order to demonstrate some of the advantages and disadvantages of model testing.

**1. The Analysis of a Redundant Frame**

During the structural design of a particular rig, it was necessary to determine the elastic stresses and deflections which would occur in the ring of rectangular section shown in Fig. 4(a). These stresses were calculated using the principal of least work, and the time taken for this was about 40 minutes.

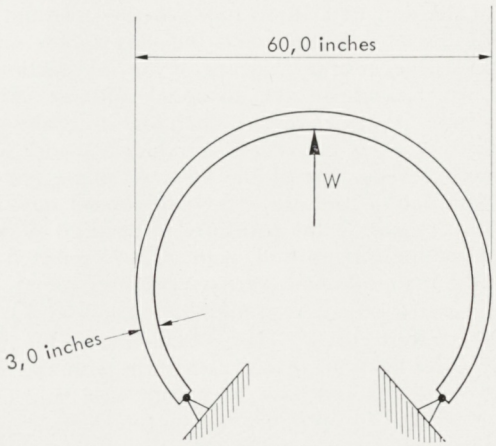



FIG. 4(a)

Redundant frame.

For the purposes of comparison of a theoretical and an experimental analysis, a two-dimensional photoelastic test was then done. A 1/10 scale model was fretsawed from a sheet of 3/16″ araldite, and the profile filed to an accuracy of about ± 0·01″. This took 30 minutes. The model was loaded in increments in the photoelastic bench, and the maximum fringe value noted at each increment. Deflection of the model was measured using a travelling microscope. This took 15 minutes. A further 15 minutes was then spent plotting these results and predicting the behaviour of the steel ring from them, using equations one and three, giving a total time of 60 minutes. Predicted stresses and deflections were approximately 10 per cent higher than those previously calculated. This degree of error was expected, due firstly, to shortcomings in the method of calculation, which ignored shear deflections and stresses other than bending stresses, and secondly, to the rather rough and ready manner in which the photoelastic test was done.

This simple comparison of theoretical and experimental methods showed that the experimental method took slightly longer than the theoretical. However, if the structure had

been complicated by the addition of diametric members for instance, then the time taken for the theoretical analysis would have been considerably longer, while that for the experimental procedure would have been very little increased. The optimum design of frame for minimum weight could also have been quickly determined experimentally by modifications to the model, material being progressively removed from points of low stress, until a uniform stress at all sections of the frame was achieved.

It is suggested that many highly redundant frames could be analysed experimentally, with a saving of time and labour over that required for a normal theoretical analysis. Possibly though, the time for a theoretical analysis could be reduced by the use of a computer—if available.

**2. Open Ship Hull Structure under Torsion**

Problems arise in providing sufficient torsional rigidity in ship hulls with large deck cut-outs, e.g. container ships.

These hulls usually consist of a closed torsion box at either end, with an open "U" section cell in between. The torsional rigidity of thin walled boxes whose cross sections are free to warp can be calculated using Batho's formula. However, the tapering at the bow of a ship's hull provides restraint against warping of the bow section, and the closed bow and stern sections themselves restrain warping of the "U" section. These restraints which increase the torsional stiffness cannot be calculated, and it was necessary therefore to make assumptions as to their value in order to produce a theory to calculate the overall behaviour of the hull. To prove the validity of these assumptions, model tests were carried out with the intention of comparing the measured deflections of a model of a typical containership hull, with values predicted for the model by the theory with its various assumptions.

Vybak plastic was chosen as the model material, for several reasons. These were that the elastic behaviour of the hull only was under consideration, that construction with this material was easier than it would have been with steel, and only low loads were necessary to produce measurable deflections. Fig. 6 shows the model, which was modified in stages to cover a variety of configurations, being tested.

Calculated angles of twist of the model assuming that complete warping restraint was provided, were significantly less than the measured values. However, modification of the calculations to allow for the restraint which was measured on the model gave good agreement for all the configurations which were tested.

Stress measurements showed that transverse bending of the hull sides, which had not been considered in the theoretical estimates, had a considerable effect on the stress distribution Only when this unexpected behaviour was taken into account did the theoretical estimates of the stress give fair agreement with the measured stress.

Most ships will be somewhat different from the model, and their structural behaviour cannot be predicted from measured results and equations 1, 2 and 3. However, the theory which was developed in conjunction with model tests, and whose validity was proved by the tests, should provide a method of calculating the torsional stiffness of ships whose general arrangements are similar to the model.

An attempt was made to demonstrate the high stresses which occur at the furthest forward and aft hatch corners. Since the corner radius on the model was only 0·175″, and the position of maximum stress on this corner was not known, it was not practicable to measure these stresses with resistance strain gauges. The Vybak material was therefore cut away in the corner area and replaced with an insert of photoelastically sensitive araldite. An extremely crude photoelastic measuring device was then rigged around this insert, and the fringes at

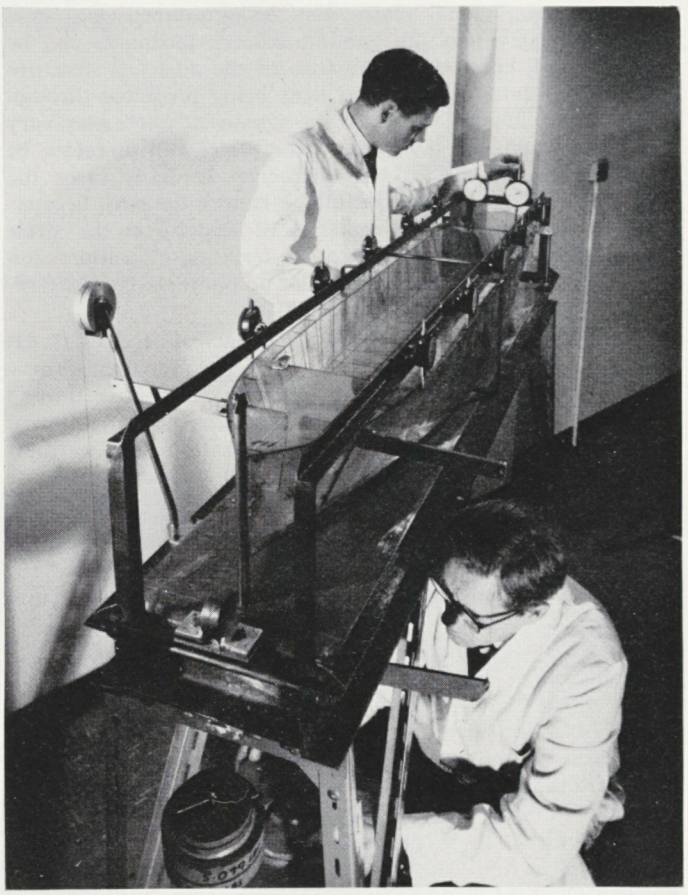


FIG. 6

Torsion tests on a plastic model of a container ship hull.

the hatch corner observed when the model was loaded. This procedure was later repeated for the corners of other hatches along the length of the model. These very inaccurate tests could not be expected to give quantitative results but they did effectively demonstrate that very high stress concentrations can occur, and permitted the determination of methods of decreasing their severity. Subsequent very approximate calculations using these results predicted to within 2 per cent and 16 per cent the maximum corner stresses which were measured on a ship to which a test torque was applied. This good agreement indicates how reliable results can be obtained from extremely crude tests.

**3. Cantilever Model**

An attempt was made to investigate with a model the mode of failure of a deck, side shell, and cantilever steel structure adjacent to a hatchway when vertical load is applied to the hatch edge.

On such a redundant structure many parts will continue to carry load after their elastic limit has been exceeded and it

was therefore essential that the model be constructed from a material with the correct post yield characteristics. As stated previously, no known plastics have these characteristics, and choice of material was therefore restricted to steel.

The problem of joining the 0·03″ thick steel components with sufficiently strong joints, whilst avoiding excessive distortions, was investigated, and argon shielded spot welding was the only procedure which appeared remotely satisfactory. Two models were therefore built using this welding process, and tested as shown in Fig. 7.

The first of these tests was unsatisfactory due to failure of the spot welds at a low load. Greater care was taken in the construction of the second model, and some success was achieved under test, in spite of a few spot welds failing prematurely.

It is obvious, however, that a better method of model construction is required if steel models at this small scale are to be satisfactory. The alternative is to increase the specimen scale so that normal welding procedures may be used, increasing greatly the costs of models, and of straining equipment.

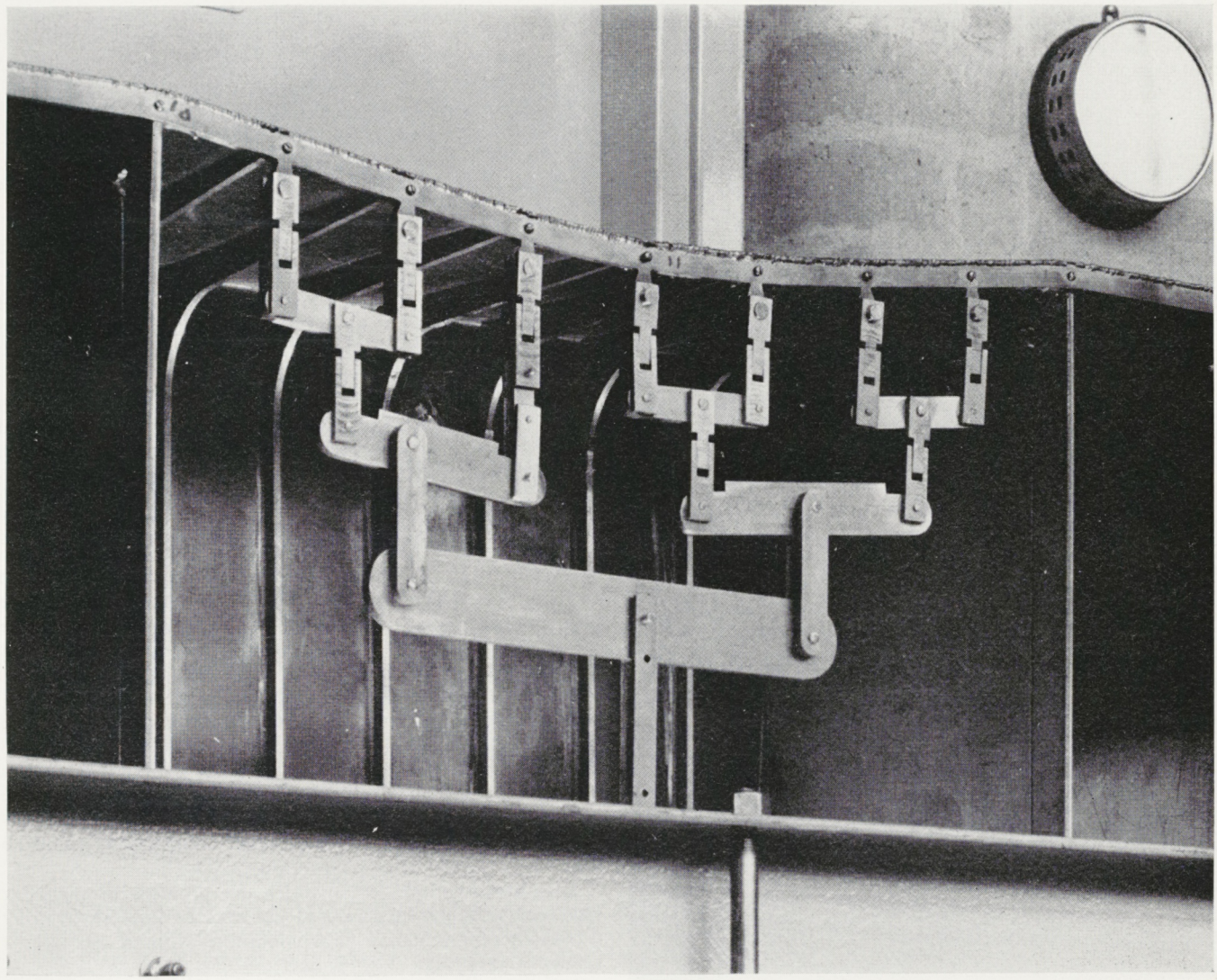


FIG. 7

Steel cantilever model loaded beyond its elastic limit.

## 4. Engine Model

During the development of a new diesel engine with several novel features, it proved impossible to calculate accurately the overall deflections of the crankcase, due to its complexity. An experimental investigation was therefore done. The ideal approach would have been to build the proposed design in steel at full scale, and to measure deflections, etc., under loads applied by hydraulic jacks. The cost of this in terms of money and time would have been high, especially since, if the tests showed that the design was unsatisfactory and required major modification, the specimen could not have been subsequently used for running tests. Therefore it was decided to construct a Vybak test model at 1/5·7 scale, and Fig. 8 shows this model in its testing frame. Equations 1, 2 and 3 were used to convert model measurements to protoype deflections and stresses.

There were 22 loading points on the crankcase, and certain loads occurred at each of these points under any condition of crankshaft angle, torque, etc. It was not possible to foresee the conditions under which the most severe distortions would occur, but to have tested for all conditions in order to have found the worst would have involved a very large number of tests with a different loading rig for each test. Therefore load was applied at a single point, and the resulting deflections measured throughout the model. This procedure was repeated for each loading point, and a table of influence coefficients was produced, from which the distortion of the crankcase under any combination of loads could be determined by the principal of superposition. Some stresses were measured at areas of low stress gradient, and the effects of several modifications were investigated.

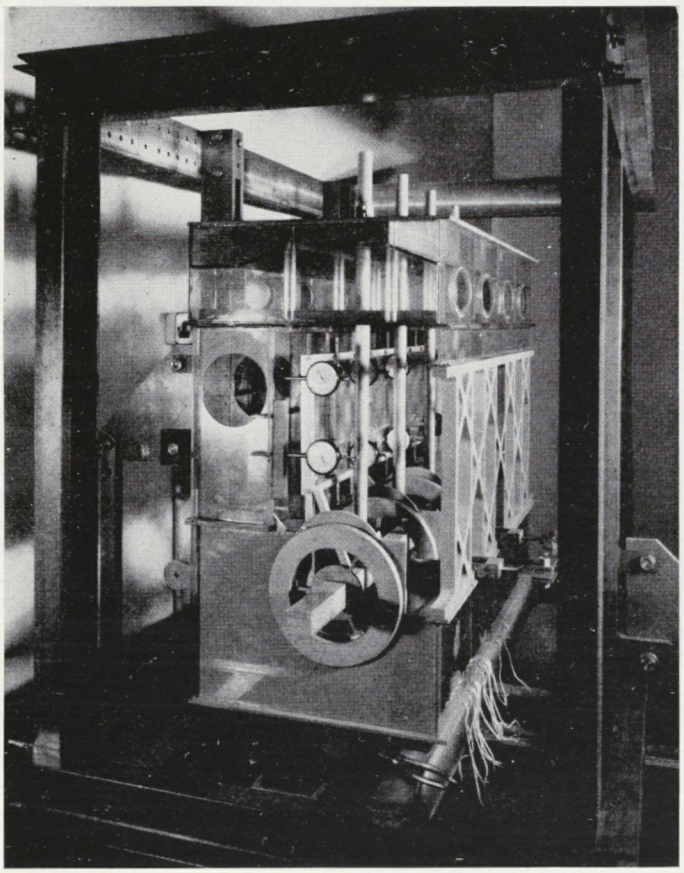


FIG. 8

1/5·7 scale plastic model of an engine crankcase. The dial gauges shown measure deflection of the guide face relative to the main bearing centre line.

Disadvantages of this model were that

(1) Bolted joints were represented by glued joints, which will not give representative local deflections and may result in small errors in overall behaviour.

(2) At local points of interest, such as a main bearing beam to guide face junction, where the somewhat complex detail design was not simulated, possible large stress concentrations could not be measured on this model. It is considered that to assess the behavour of this type of detail, a larger scale structural test of the relevant area is required.

The tests showed that certain areas of the proposed crankcase were insufficiently stiff and that the front cross bracing carried very low loads so that some of it could possibly be dispensed with. Time from decision to commence investigation to completion of report was 15 weeks.

## 5. Bulk Carrier Model

Fig. 9 shows a Vybak model of the double bottom of a bulk carrier under test. Compensating ring loading technique is used, distributed load being applied through sponge rubber pads.

This is a scale model of an existing ship on which stress measurements had been made under the alternate hold loaded condition. It was hoped to compare ship and model results with calculated results to prove both the model testing technique and the method of calculation.

0·03″ thick sheet was considered to be the minimum thickness which could be used on the model, and this resulted in a scale of 1/25. In order to get the correct conditions at the two holds at which measurements were made, it would have been necessary to include several of the adjacent holds on the model, but this would have resulted in a model so large that it could not be accommodated in the workshop. Two holds only were therefore built and tested with known but unrepresentative end conditions: These conditions can be represented in the calculated hull behaviour, and the resulting calculated deflections and stresses agreed reasonably well with the values measured on the model. Measurements made on the ship were affected by thermal stresses induced by the sun, and no satisfactory ship-model or ship-calculated comparisons could be made.

This investigation demonstrates the problem of including sufficient surround structure to the area of interest, in order to obtain representative edge conditions without too large a specimen resulting.

It is thought that too much detail was included in the model, and that a smaller scale could have been used with advantage. Plate thicknesses would then have had to be scaled to a different factor to all the other dimensions if they were not to be impossibly small, but this would probably not have produced significant errors.

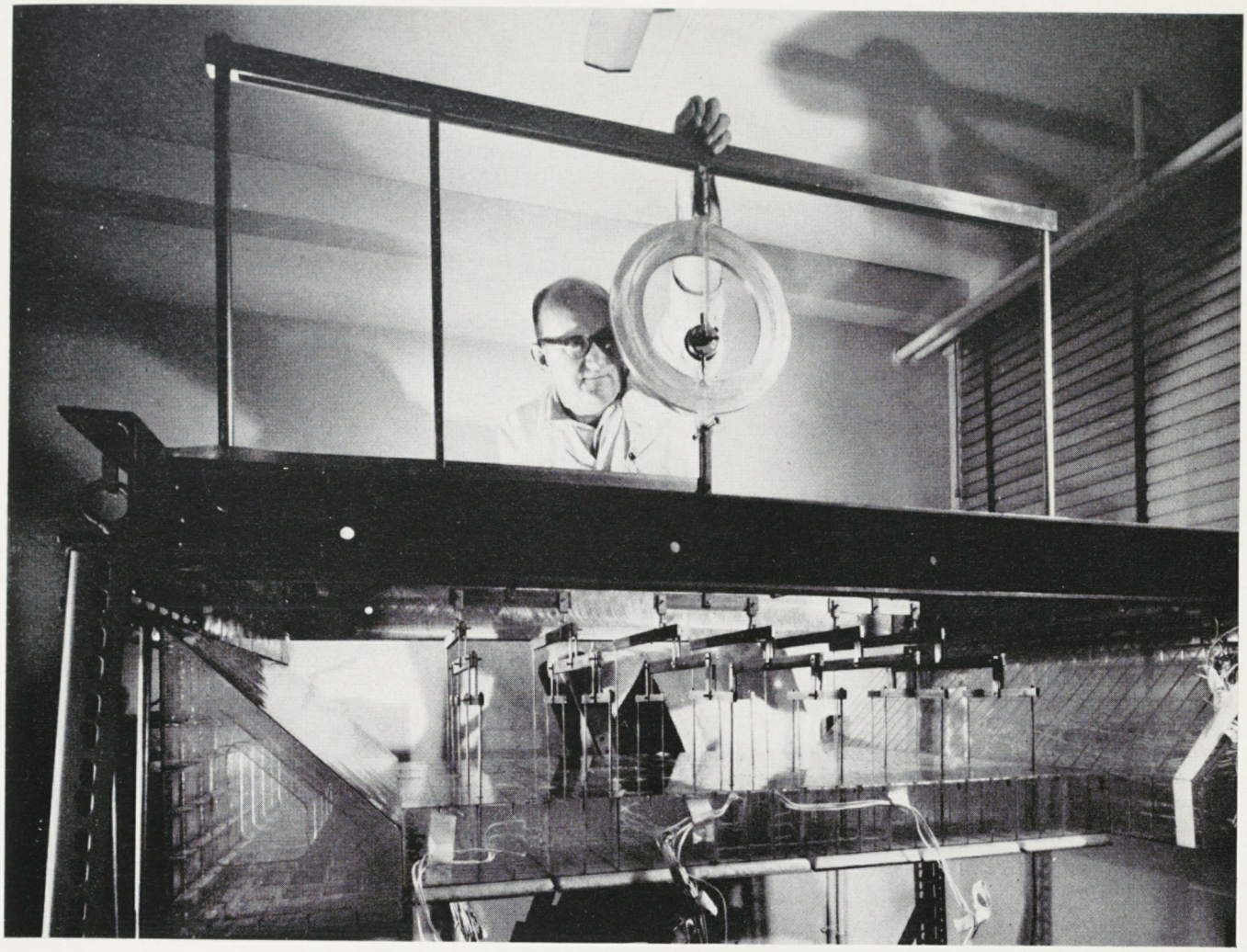


FIG. 9

1/25 scale plastic model of the double bottom of ore hold of a bulk carrier. Load is applied by a screw jack via compensating ring, "whiffle tree" and sponge rubber pads. For subsequent tests transverse stools, corrugated bulkheads, hull sides and a second hold were added.

## CONCLUSION

Model testing has become widely accepted as a cheap, rapid and reliable tool in structural design in the same way as it has long been established in such fields as aerodynamics and hydrodynamics. It allows the designer to design with confidence structures such as were investigated with the open ship and engine models, where no theoretical analysis nor similar structures to provide reliable design yardsticks exist. At the same time it gives a more complete understanding of the behaviour of accepted structural details, knee brackets for instance, and should therefore lead to more economic design.

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# APPENDIX

### Photoelastic Theory

Light is passed through the polariser, and on emerging its wave amplitude = a cos wt.

On entering the stressed model this wave splits into two components U and V resolved along the directions of the principal stresses P and Q (*see* Fig. 4(b)).

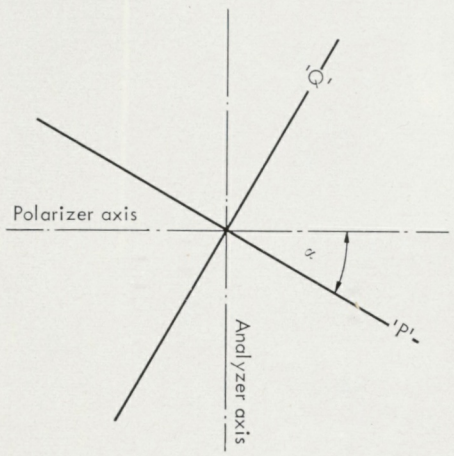


FIG. 4(b)

$U = a \cos wt \cos \alpha$

$V = a \cos wt \sin \alpha$

On passage through the model the V wave is retarded by a phase angle $\theta$ with respect to the U wave $\theta \propto (P-Q)$.

$\therefore$ On leaving the model $U = a \cos wt \cos \alpha$

$V' = a \cos (wt - \theta) \sin \alpha$

With polariser and analyser crossed, light (R) emerging from analyser equals the algebraic sum of the resolutes of these two waves on the analyser axis.

$$R = V' \cos \alpha - U \sin \alpha$$

$$= a \cos (wt - \theta) \cos \alpha \sin \alpha - a \cos wt \cos \alpha \sin \alpha$$

$$= a \cos \alpha \sin \alpha \, (\cos (wt - \theta) - \cos wt)$$

$$= \frac{a}{2} \sin 2\alpha \cdot 2 \sin \left( wt - \frac{\theta}{2} \right) \sin \frac{\theta}{2}$$

$$= a \sin 2\alpha \cdot \sin \frac{\theta}{2} \sin \left( wt - \frac{\theta}{2} \right)$$

$$= \text{a vibration of amplitude } \left( a \sin 2\alpha \cdot \sin \frac{\theta}{2} \right)$$

$\therefore$ light intensity $= \left( a \sin 2\alpha \cdot \sin \frac{\theta}{2} \right)^2$

This is zero, and no light will pass if

(1) $\sin 2\alpha = 0$, i.e. $\alpha = 0$; $\frac{\pi}{2}$ etc., when the plane of the polariser and analyser are aligned with the principal stresses.

or

(2) $\sin \frac{\theta}{2} = 0$, i.e. $\theta = 0, 2\pi, 4\pi$, etc.

This is where the relative retardation is equal to an integral number of wavelengths 0, 1, 2 or 3, etc., which gives dark fringes referred to as fringe 0, 1, 2 or 3, etc.

Then $P-Q = \frac{Nf}{T}$

Where N is the fringe number.
f is the material constant.
T is the material thickness.

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# FIRE DETECTION IN UNATTENDED MACHINERY SPACES

J. D. Bolding

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Hon. Sec. T. Swiatecki
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# FIRE DETECTION IN UNATTENDED MACHINERY SPACES

By J. D. Bolding

A fire detection system is required by all Classification Societies in Unattended Machinery Spaces. This paper considers fire detection systems under the following headings:—

1. Fire detector heads.
2. Control panels.
3. Location and selection of detectors for specific applications.
4. Testing of completed systems.

## 1. DETECTOR HEADS

Six methods of detection are used:—

(1) Combustion products detectors which operate when large particles enter an ionization chamber.

(2) Photoelectric cells which operate when a light beam is scattered by smoke particles.

(3) Photoelectric cells which operate when a light source is obscured by smoke.

(4) Heat detectors which operate when the rate of rise of air temperature exceeds a pre-set rate.

(5) Heat detectors which operate when the air temperature rises above a pre-set level.

(6) Infra-red heat detectors which sense radiated heat from flame.

Some detector heads combine more than one of the above; (4) and (5) are often combined.

### (1) Combustion Products Detectors (Ionization Chamber)

Most of these use two irradiated gaps in series as shown in Fig. 1(a), (b) and (c).

Gap "A" is open to the atmosphere while Gap "B" is enclosed (*see* Fig. 1(a)).

The presence of the radioactive source introduces free ions in the gaps permitting a leakage current to pass (*see* Fig. 1(b)). The gaps can be considered as very high resistors having values depending on the configurations of each gap, and the amount of radiation present. Hence the supply voltage is divided to give an output voltage which is connected to a triggering device.

When most substances burn the combustion products are large particles made up of molecules linked in chains.

These particles find their way into Gap "A" and absorb some of the ions, so increasing the effective resistance of the gap. This alters the voltage across the potential divider and the trigger circuit operates (*see* Fig. 1(c)).

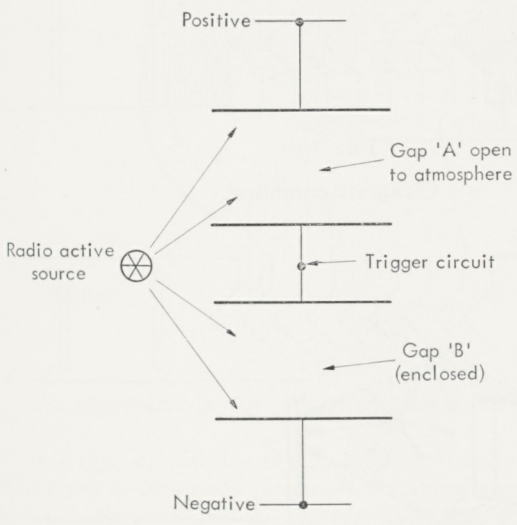


FIG. 1(a)

Layout of Combustion Products Detector.

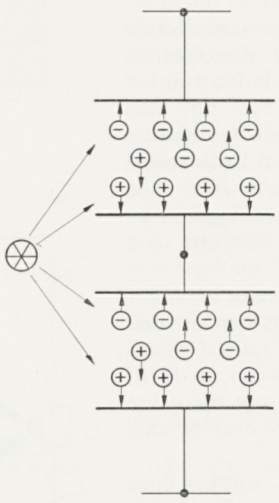

FIG. 1(b)

Normal operation, no particles present.

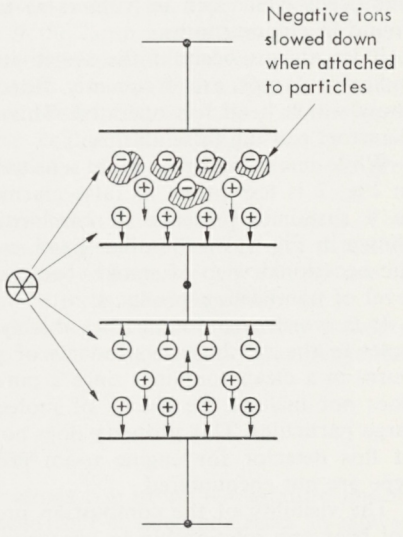


FIG. 1(c)

Particles generated by fire present.

The sensitivity may be adjusted by changing the balance of radiation between the gaps or by altering the triggering voltage.

Another detector of this type uses an irradiated gap and a capacitor as shown in Fig. 2.

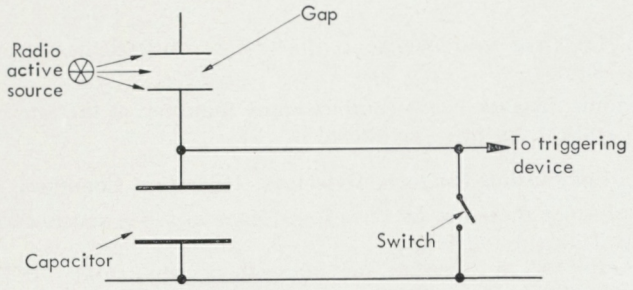


FIG. 2

Integrating Combustion Products Detector.

Operation depends on the small current flow through the irradiated gap causing a voltage to build up on the capacitor in a given time.

If the voltage does not build up due to the presence of combustion products in the gap, the alarm is triggered. At the end of each time-interval the capacitor is discharged, and the charge process is re-started. The charging period is in the order of about half a minute, and sensitivity can be varied by altering this period.

Some examples of triggering circuits are included in Appendix I.

The combustion products detector can be adjusted to a high sensitivity and it is suitable for engine room protection.

Advantages include the absence of filament lamps and photocells which can be vulnerable to the dirt and vibration found in engine rooms.

False alarms occur if the sensitivity is set too high. Small indicator lamps are frequently fitted to these detectors to show which head has operated. This feature aids location of detectors causing false alarms.

While maintaining a high sensitivity the detector shown in Fig. 2 is less prone to false alarms because it only reacts to a sustained presence of combustion products. The type shown in Fig. 1, on the other hand, can easily be triggered by the occasional wisp of smoke, because it reacts instantly to a level of combustion products.

It is worth mentioning that this type of detector will not react to the combustion products of pure alcohol or acetone burnt in a clean container since a pure gas is produced which does not include the chains of molecules necessary to form large particules. This property does not detract from the value of this detector for engine room protection as fires of this type are not encountered.

The visibility of the combustion products (i.e. smoke) does not bear any relationship to triggering level. A small exhaust leak from a diesel engine will set off the detector very easily but a visible concentration of smoke from over-heated electrical insulation will not. The detector reacts to the number of particles present; size is not important. Hence a large number of relatively small particles, though invisible, will set off the detector, while a smaller number of larger particles, forming an opaque cloud, will not.

(2) **Light-scatter Smoke Detectors**

These detectors make use of the Tyndall Effect (Fig. 3(a), (b) and (c)).

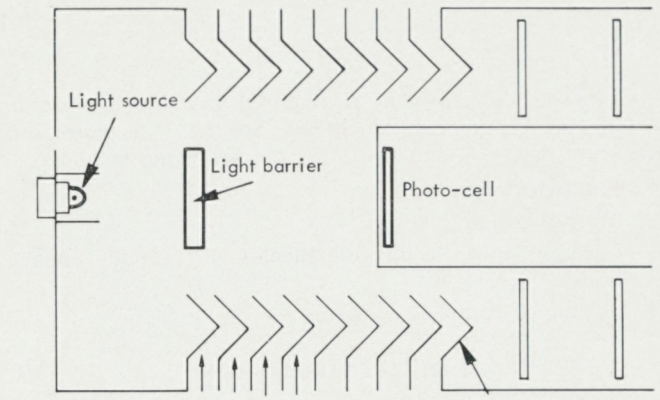


FIG. 3(a)

Layout of Light-scatter Smoke Detector.

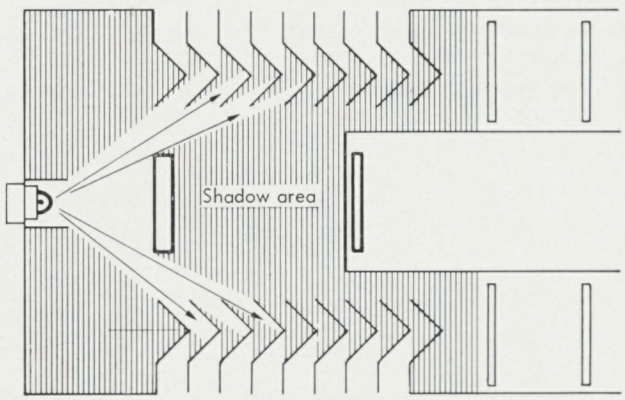


FIG. 3(b)

Clean air condition.

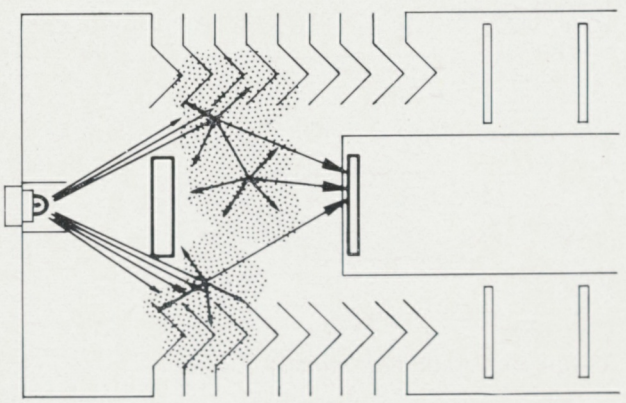

FIG. 3(c)

Smoke condition.

Fig. 3(a) shows a light source obscured from a photocell by a barrier.

When there are no smoke particles, oil droplets, dust or steam vapour in the atmosphere, no light falls upon the photocell (Fig. 3(b)).

When particles enter the detector, the light beam is scattered onto the photocell and the alarm operates. (Fig. 3(c).)

The arrangement is more sensitive than the obscuration type described later. The small voltage generated in the photocell is amplified to actuate the alarm devices.

To avoid the pickup problems which would occur if the photocell signal were cabled back to the control panel, the amplifier is built into the detector head.

Some disadvantages associated with this type of detector are:—

(a) Failure of the lamp renders the detector inoperative.

(b) Many types of lamp are vulnerable to vibration and have an unpredictable life.

(c) Photocells can be vulnerable to vibration and contamination.

Some of the methods of overcoming these potential sources of weakness, and details of the amplifiers and alarms circuits employed, are given in Appendix II.

It is not essential for the lamp and photocell to be arranged opposite to each other. The lamp beam can be arranged to pass at right angles to the axis of the photocell as shown in Fig. 4.

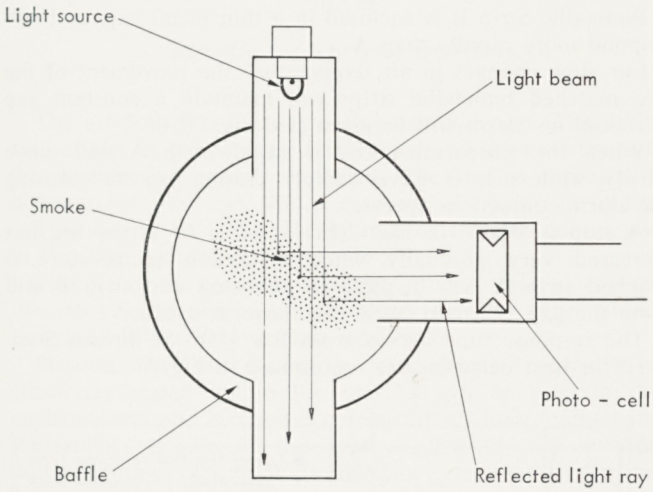


FIG. 4

An alternative layout of Light-scatter Smoke Detector.

This type of detector is also used on systems having a fan and pipes to continuously sample the atmosphere from potential fire outbreak points. These systems are similar to those used for cargo hold protection, but use pipes solely for detection purposes, instead of using $CO_2$ pipes. Because the smoke is diluted by using a number of sampling points, and only one detector is used its sensitivity must be extremely high. This raises temperature stability problems. Also, because the failure of the one detector would render the system totally inoperative, extra surveillance of the detector head itself is essential. (*See* Appendix II.)

(3) **Obscuration Type Smoke Detectors**

The operation of this type is self evident, and a typical arrangement is shown in Fig. 5.

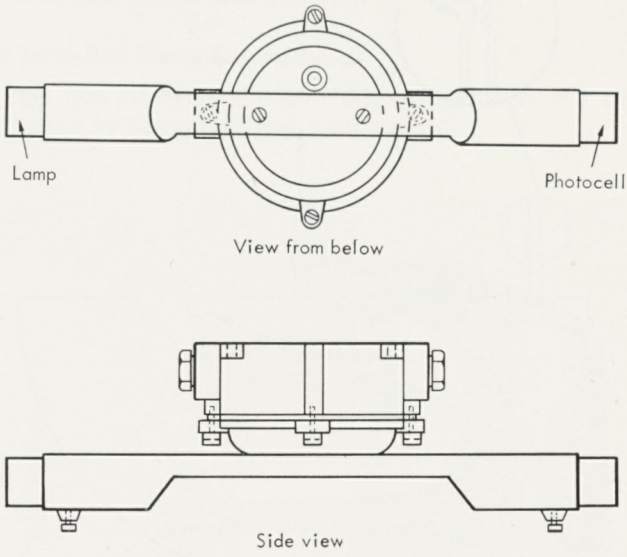


FIG. 5

Obscuration Type Smoke Detector.

Smoke obscures the light from the lamp, reduces the current through the photocell and causes the alarm to sound. At the present time it is not possible to make small deckhead mounted detectors operating on this principle as sensitive as the detectors discussed previously. This type of detector can be made more sensitive if the lamp and photocell are separated from each other as individual units since a longer light beam can be used. The Author is not aware of such a system being used in ships' engine rooms. Contamination of the lenses and the lighting in the engine room could render them inoperative. There appears to be no reason why these problems could not be solved.

A detector using a laser beam is under development. This uses two separate units as suggested above, but fire detection does not rely on obscuration. Changes in air density due to heat operate this type of detector. (*See* Appendix III.)

The obscuration principle is used as a laboratory standard for measuring the performance of detectors. (*See* Appendix IV.)

(4) **Rate of Rise Detectors**

This type of detector senses rise in air temperature due to fire. The sensitivity is such that it does not react to slower rises in air temperature due to room heating.

Two basic methods of sensing rate of rise of temperature are used. The first is shown diagrammatically in Fig. 6.

Changes in air temperature expand the air inside the hemisphere. If the rate of change in temperature is slow, the air is released through the fine orifice without moving the diaphragm. If the rate of change is fast, the resulting pressure moves the diaphragm and operates the alarm.

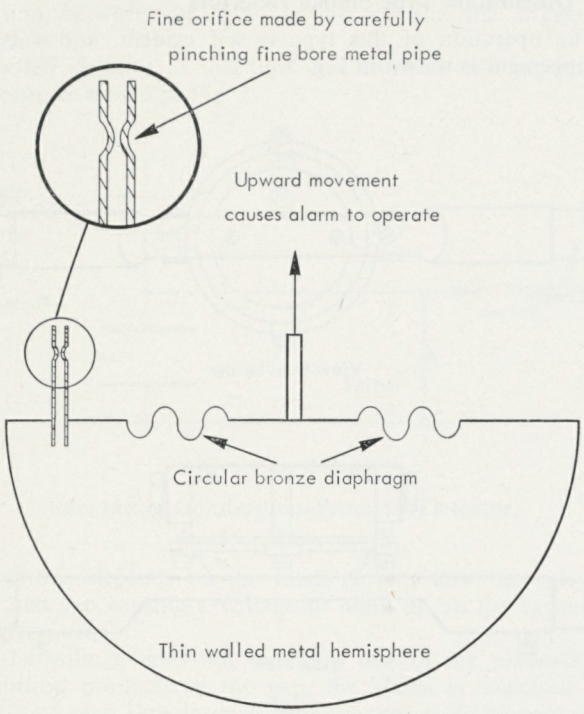


FIG. 6

Pneumatic Type Rate of Rise Detector.

The second method relies on the difference in thermal inertia between two temperature sensing devices (*see* Fig. 7(a) and (b)).

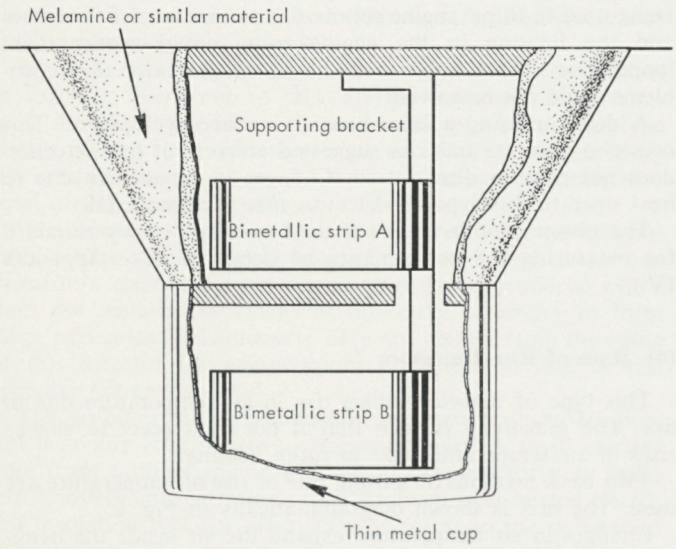


FIG. 7(a)

Layout of Thermal Inertia Rate of Rise Detector.

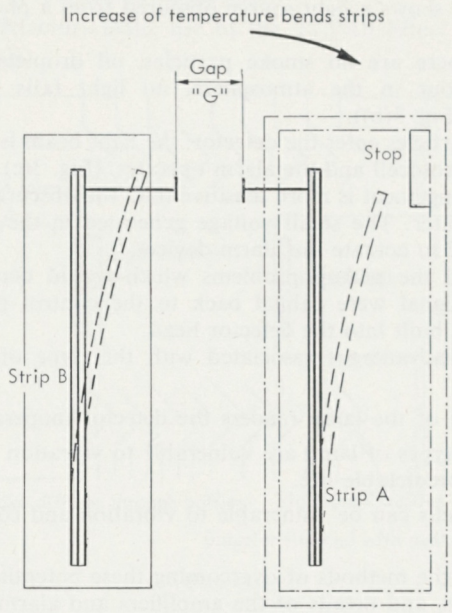


FIG. 7(b)

Operating principle.

Bimetallic Strip A is enclosed in Melamine and is insulated from sudden changes in temperature.

Bimetallic Strip B is enclosed in a thin metal cap, and will respond more rapidly than A.

For slow changes in air temperature the movement of the two matched bimetallic strips will maintain a constant gap "G" and no alarm will be given (*see* Fig. 7(b)).

When the temperature rise is rapid, strip A will move slowly, while strip B moves rapidly, closing gap "G" causing the alarm contacts to operate.

A stop is shown in Fig. 7(b) for strip A. If the fire has increased very gradually when a certain temperature is reached strip A will be held by the stop and strip B will close the gap "G" and cause the alarm to operate.

The response time curves from B.S. 3116 the British Standard for heat detectors are reproduced in Fig. 8.

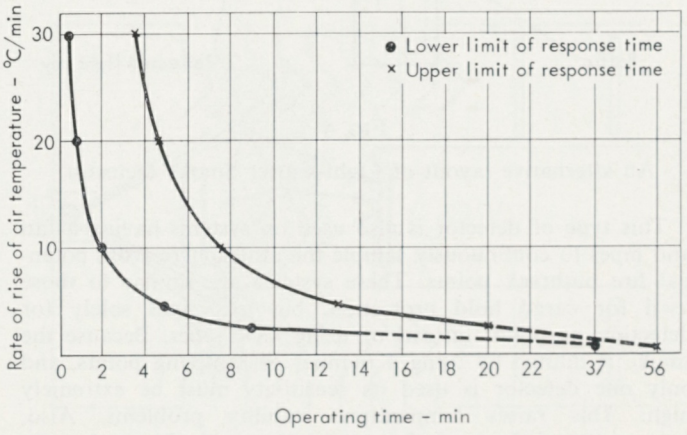


FIG. 8

B.S. 3116 Response requirements for Thermal Detectors.

A typical test rig for type testing rate of rise detectors is shown in Fig. 9.

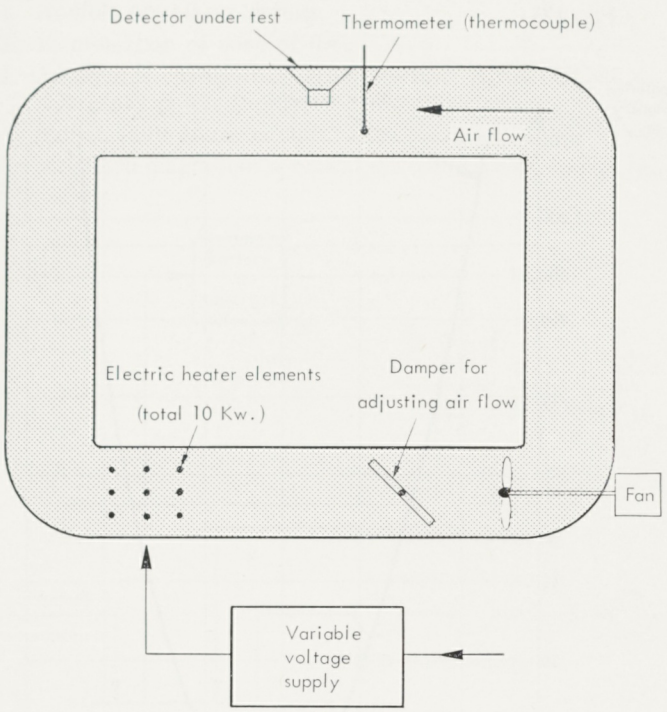


FIG. 9

Test Rig for Thermal Detectors.

The air-flow is adjusted to the specified rate. The desired rate of rise of temperature is obtained and the time taken for the detector to operate is noted. The test is repeated for different rates of rise, and a response characteristic plotted. This should lie within the bounds of the two curves given in Fig. 8 to meet B.S. 3116.

This detector is generally less susceptible to false alarms than the smoke and combustion products detector types already described. It is, however, less sensitive.

Because the internal parts can, where necessary, be effectively sealed within the unit, it can be used in dirty environments and it requires comparatively little maintenance. Watertight versions of this type of detector are available. Some examples of rate of rise detectors are given in Appendix V.

It should be pointed out that detectors relying solely on rate of rise are very rarely used without the inclusion of a fixed temperature sensing device (e.g. the stop shown in Fig. 7(b)).

### (5) **Fixed Temperature Detectors**

The two most commonly used sensors for operating this detector are bimetallic strips and low melting point soldered links which release when heated.

It is suitable for conditions where rapid variations of temperature are likely, e.g. close to a boiler.

The Society does not accept detectors in unattended machinery spaces which utilise low melting point solder because they cannot be tested satisfactorily on the ship. Also, after prolonged exposure to vibration and high temperature the semi-plastic metal is prone to failure.

Some examples of fixed temperature detectors are given in Appendix VI.

In most applications, the fixed temperature detector is less sensitive than the foregoing detectors.

### (6) **Infra-Red Flame Detectors**

This type of detector senses the radiated heat and light given out by flames (*see* Fig. 10(a) and (b)).

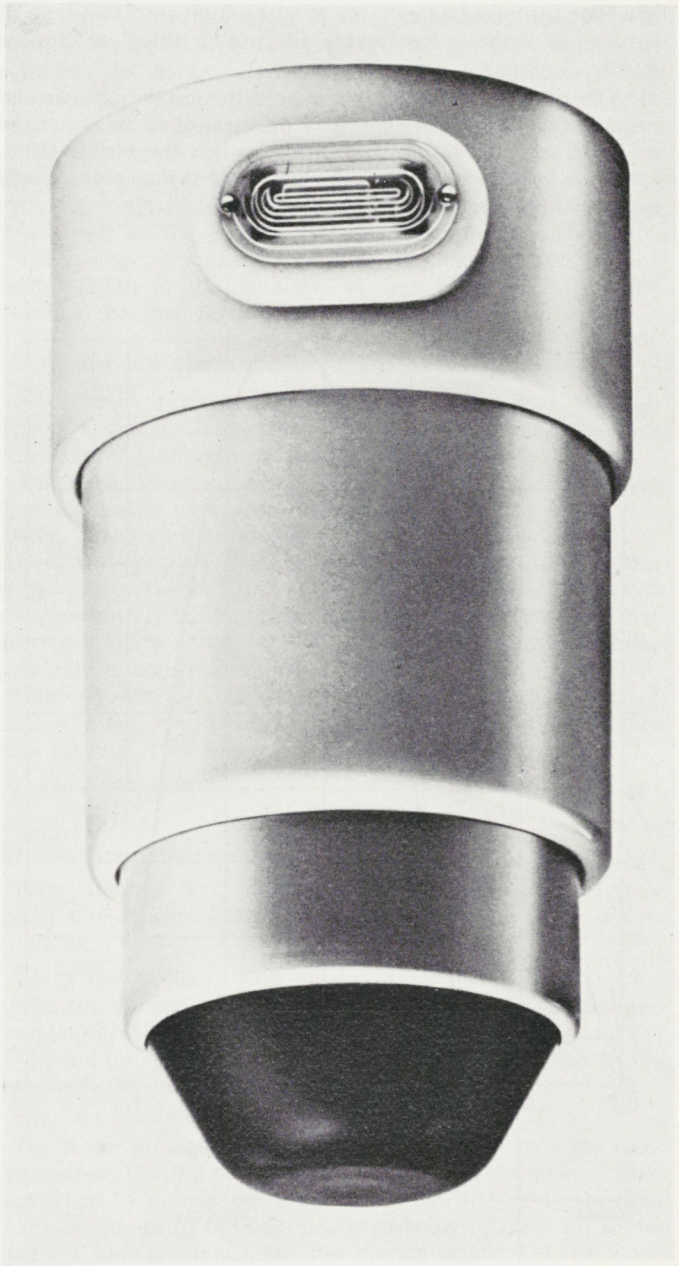

FIG. 10(a)

Infra-red Flame Detector.

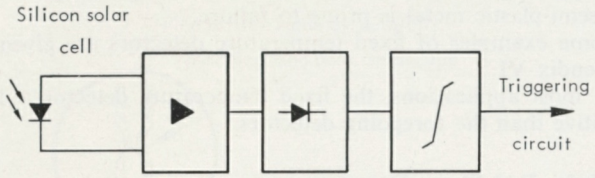


FIG. 10(b)

Block diagram.

To avoid response to other sources of radiated heat and light, the following safeguards must be built into this type of detector to make it acceptable for use in ships' machinery spaces.

(a) The characteristics of the solar cell must be chosen and suitably filtered so that it is only sensitive to a narrow band of infra-red frequencies, close to the visible band. Thus heat radiation from hot parts of the machinery will not affect the detector (*see* Fig. 11).

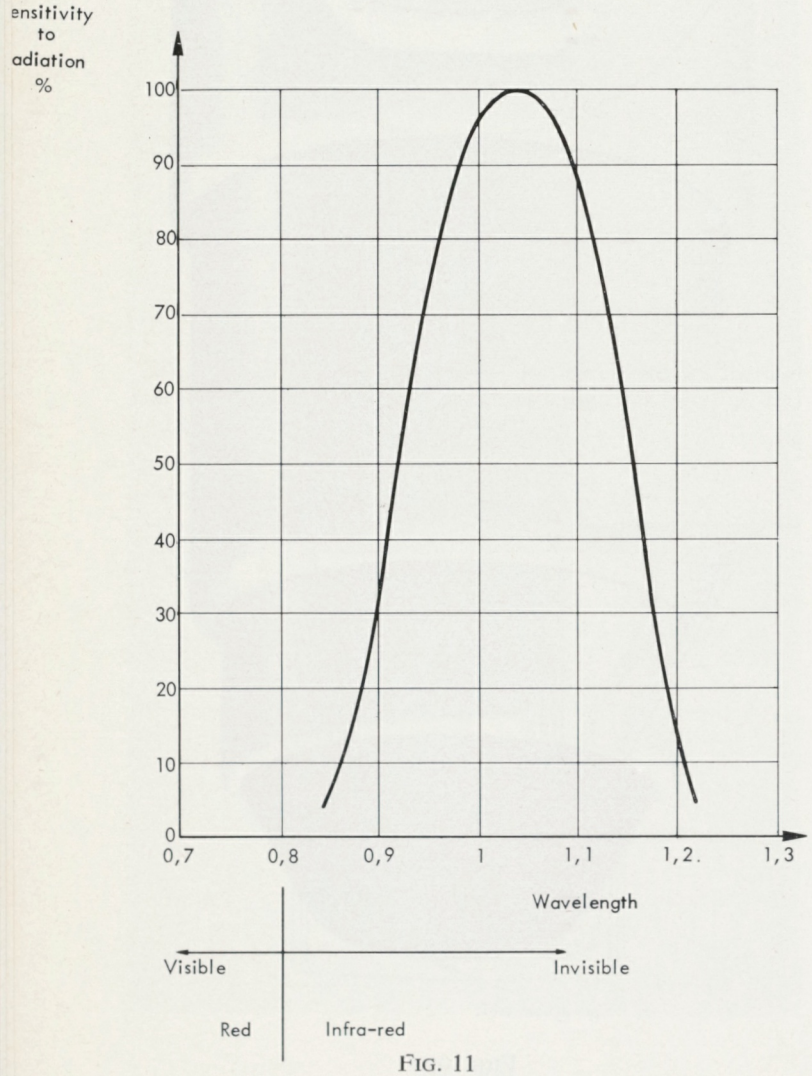


FIG. 11

Band width of Solar Cell and Filter.

(b) The solid state amplifier is not directly coupled to read the direct current output of the solar cell, but is tuned to respond to the flickering characteristics of flames (*see* Fig. 12).

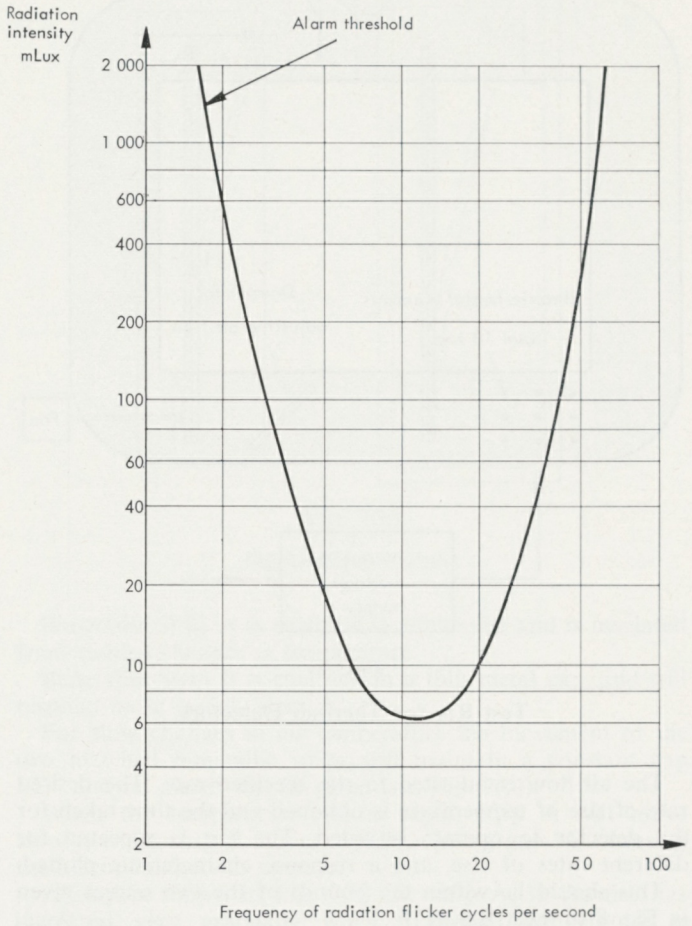


FIG. 12

Alarm threshold variation with flicker frequency.

This frequency range has been found to be a characteristic of flames more than an inch or so long.

(c) As a further safeguard, integration of the output is used to avoid false alarms. This ensures that the alarm does not operate for random false signals equivalent to a small fire but will operate if a small flame persists.

Great care is required in siting this detector because the amplifiers can be "paralysed" by sunlight or nearby engine room lighting. Similarly, reflection of light from a vibrating or rotating piece of machinery such as a belt driven compressor with a spoked pulley, can cause false alarms. All of these problems can be anticipated by careful testing at the commissioning stage.

As this detector is operating close to the visible spectrum, the flames can be masked from the detector by smoke. Therefore, the infra-red detector must be used in conjunction with others operating on a different principle.

## 2. CONTROL PANELS

The following features are incorporated in control panels: —

1. Audible fire alarm circuits.
2. Identification of zone of fire.
3. Automatic change-over from normal power supply to emergency power supply.
4. System fault alarm circuits.

A simplified diagram of a typical system is shown in Fig. 13.

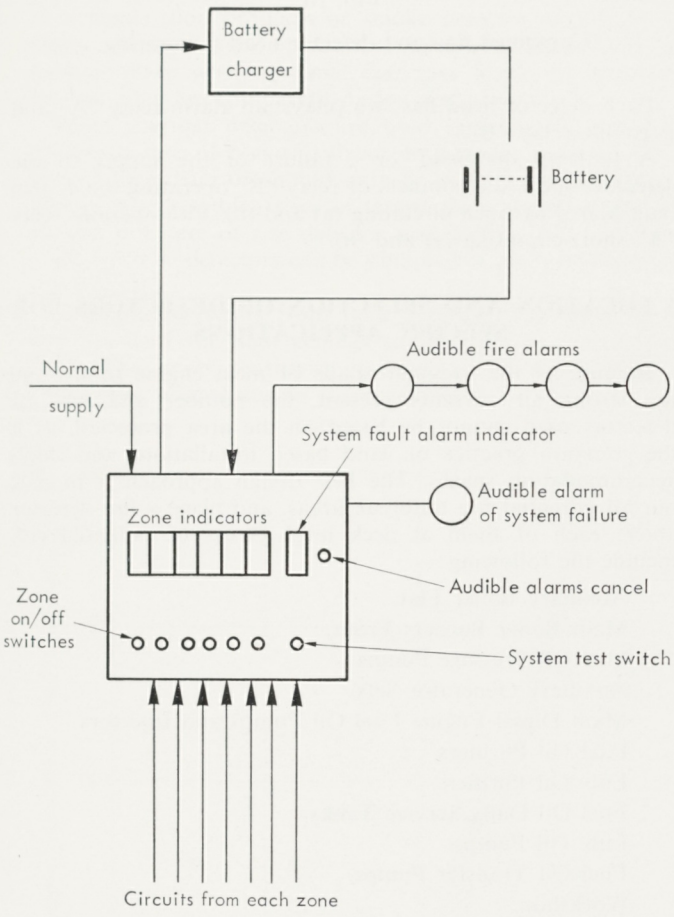


FIG. 13

Diagram of Control Panel.

A few examples of the logic used in these circuits appear in Appendix VII and many of the circuits in Appendix II are also relevant.

### 1. Audible Fire Alarm Circuits

These are normally relay operated from the zone identification circuits.

It is common to give an interrupted audible signal when the alarm is operated by a fire detector and a continuous signal when it is set off by a manually operated switch.

Silencing of the alarm is carried out by a pre-set switch which should only be accessible to a responsible officer, i.e. a key operated switch, or a switch housed behind a locked door in the control panel.

### 2. Identification of Zone of Fire

Groups of fire detectors are arranged in circuits according to their position in the machinery space. When a fire starts in a zone, this is indicated on the alarm panel.

The zoning is usually fairly wide ranging. For a large cargo ship, four zones are typical, such as forward, aft, port and starboard. When purifier flats, generator rooms, storerooms and workshops are enclosed, they should each have a separate zone.

### 3. Automatic Change-over on Power Failure

The majority of systems operate on 24V d.c. and the circuits are connected across the standby battery. The current for the alarms is fed from a battery charger which also maintains the battery in the fully charged condition. Some systems operate at mains voltage (e.g. 220V 50 or 60c/s). In such cases the emergency battery supply is changed from a 24V d.c. supply into a 220V a.c. supply, by means of an inverter (*see* Appendix VIII). With this system the detectors are fed directly from the mains under normal conditions, and switch over to the battery and inverter upon mains failure.

The emergency battery should be capable of operating the alarm system in the no-alarm state for six hours, and of sounding the Fire Alarms for half-an-hour.

### 4. System Fault Alarm Actuating Circuits

Self checking circuits are included in detector systems. When a system fault occurs, it is normal to sound a subsidiary alarm rather than cause the fire alarms to operate.

The most obvious fault is power failure. Hence when the system changes over from mains supply to the emergency supply, the alarm is sounded. Some systems include a dry battery to operate the alarm in case the battery is the cause of the power failure. This is rarely used on ships, and is not so important if the change-over system is designed so that either the mains or the battery can supply the system without interference from the other.

Cables to the detectors are also checked. This is important because a fire could damage the cables before the detectors have reacted. Two basic methods are used: —

(a) Loop monitoring

and

(b) Line termination monitoring.

Both systems rely on the detecting devices being open circuit under normal conditions, and conducting in the alarm condition.

Loop monitoring is shown in Fig. 14.

The fire alarms are actuated by closure of the contacts or conducting devices in the detector heads through (a) and (b) while continuity of the circuits is checked through (a) to (d) and (b) to (c) (*see* Appendix VII).

Line termination monitoring is shown in Fig. 15.

As in the previous case, the alarms operate when the contacts across (a) and (b) close. However, the continuity of line is checked by monitoring the resistance at the end of the line. If the resistance of the line measured across (a) and (b) is less than the end resistance, the fire alarms sound. On the other hand, if the resistance measured across (a) and (b) increases above a predetermined level equal to the resistance plus an allowance for cables and connections, the system fault alarm is actuated.

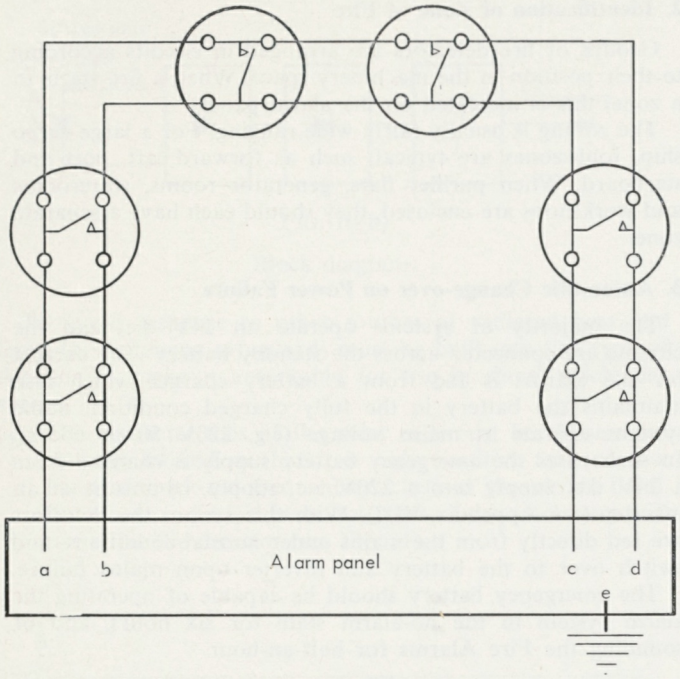


FIG. 14

Loop monitoring of cables.

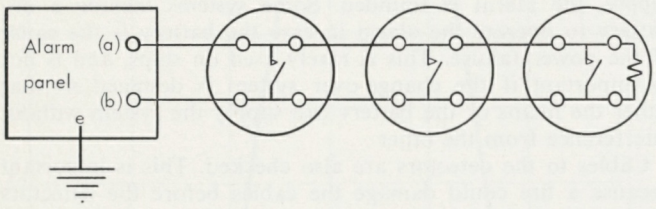


FIG. 15

Line termination monitoring of cables.

Some manufacturers use zener diodes instead of end resistors. The result is basically the same.

Earth leakage monitoring is also occasionally employed in conjunction with the two methods already discussed. The circuit in this instance monitors the insulation resistance between earth (e) on Figs. 14 and 15 and the remainder of the circuit (a), (b), (c) and (d).

An alarm may be given when the insulation reaches a predetermined low level. Alternatively, an indication is given on a meter or lamps when demanded by the operator. This feature is not as essential as cable continuity monitoring and may be regarded as a useful maintenance facility.

The instructions issued with the control panel should make clear that an alarm indicating loss of continuity of a fire detector circuit should be investigated immediately, in case a fire has caused the fault.

Other system fault monitoring circuits check the individual components and circuits to a greater depth (*see* Appendix II).

A system including line and detector head circuit monitoring is shown in Fig. 16.

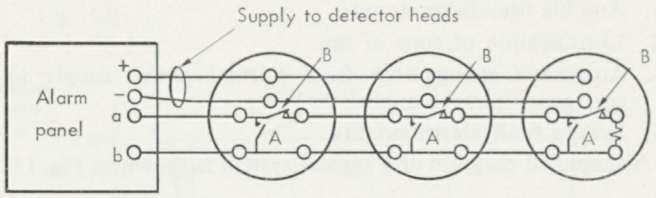


FIG. 16

Combined line and detector head monitoring.

Each detector head has two relays, an alarm relay "A" and a trouble relay "B".

A fault in the head, or a failure of the supply to the detector, opens the contacts of relay "B" operating the system fault alarm by open circuiting (a) and (b). Fire operates relay "A" short-circuiting (a) and (b).

## 3. LOCATION AND SELECTION OF DETECTORS FOR SPECIFIC APPLICATIONS

Because of the irregular shape of most engine rooms and the strong air currents present, the number and type of detectors used cannot be based on the area protected, as is the common practice on land based installations and ship's accommodation spaces. The best design approach is to pick out all potential fire outbreak areas, and place a fire detector above each of them at deck level. Areas of potential risk include the following:—

Auxiliary Boiler Flat.
Main Boiler Burners Front.
Fuel Oil Pressure Pumps.
Auxiliary Generator Sets.
Main Diesel Engine Fuel Oil Pumps and Injectors.
Fuel Oil Purifiers.
Lub. Oil Purifiers.
Fuel Oil Daily Service Tanks.
Lub. Oil Pumps.
Fuel Oil Transfer Pumps.
Workshop.
Electrical Switchboard.
Storerooms.
Oily Bilge.

Additional detectors can then be sited at a fairly wide spacing to give general cover to areas not containing special risks.

The type of detector used, will be governed by the height of the deck head, the extent to which the machinery space has been split into compartments, and the dirtyness of the particular location. Generally, combustion products or light-scatter detectors will be found most suitable where the machinery space is higher than three metres. They are also suitable for high risk areas which are not enclosed. The high sensitivity of these types of detector gives the operating staff early warning of an outbreak of fire.

Because of their low sensitivity, thermal detectors are not suitable for use in high open areas of the machinery. Their sensitivity is acceptable in enclosed areas, having low deck

heights. Heat from the fire is then sufficiently confined to give early warning and the possibility of fire spreading from an enclosed area is less than in open areas. They are, for instance, suitable for use in enclosed purifier flats, auxiliary boiler rooms, and in the confined area of the funnel. In all these situations dirt would make it necessary for combustion products, and light-scatter detectors to be cleaned frequently.

Also, when the workshops are reasonably well enclosed (i.e. only small areas of wire grill in the partitions), and it is intended to braze or carry out similar burning operations, thermal detectors would be acceptable in these circumstances as a combustion products or smoke detector would give an alarm during such operations. Enclosed storerooms are another place where thermal detectors would be acceptable because they are comparatively low risk areas.

When thermal detectors are used they should be of the combined rate of rise and fixed temperature type. The fixed temperature detector should only be used in unusual circumstances where sudden rises in temperature would cause false alarms, if a rate of rise detector was used.

Rate of rise detectors can be obtained in various sensitivities (*see* Fig. 17).

This grading stems from land practice. The higher sensitivity is used for high ceilings so that fire can be detected early. The lower sensitivity is required for low ceilings to avoid false alarms due to room heating.

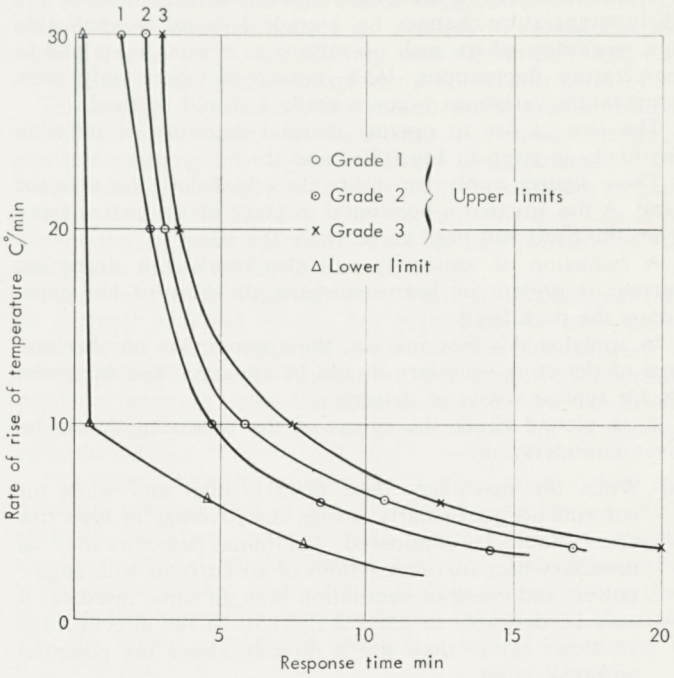


FIG. 17

Sensitivity grading of Rate of Rise Detectors.

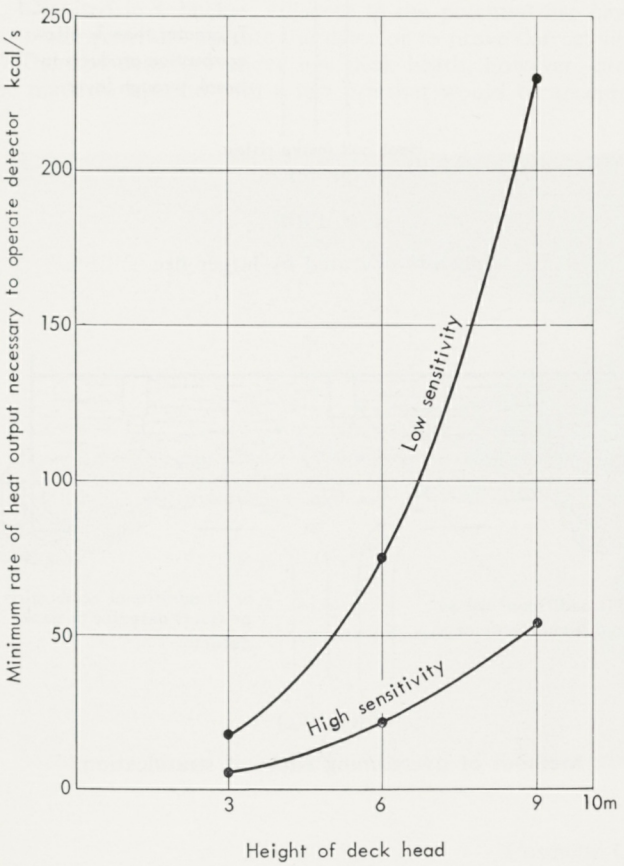


FIG. 18(a)

Minimum heat output necessary to operate Rate of Rise Detectors with slow developing fire 5° C/minute.

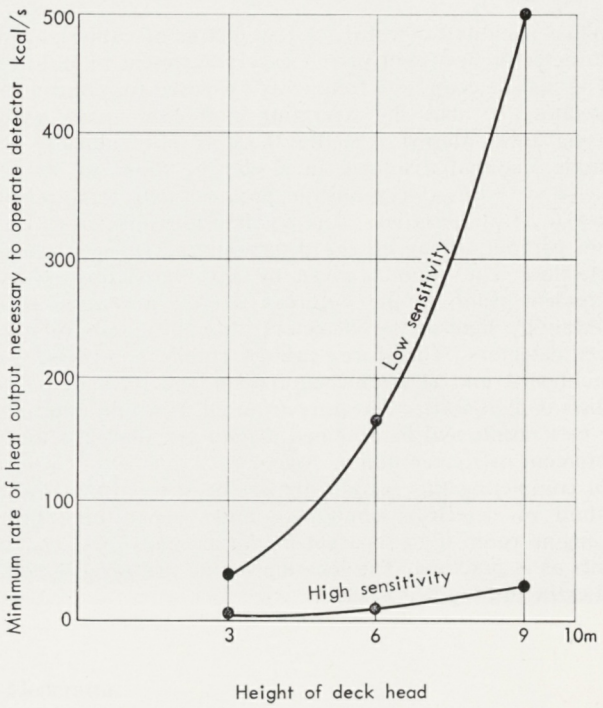


FIG. 18(b)

Minimum heat output necessary to operate Rate of Rise Detectors with rapidly developing fire 30° C/minute.

The grades used in machinery spaces will depend upon the likely temperature changes, i.e. a grade 3 would be applicable in a workshop where such operations as brazing may lead to temperature fluctuations. In a storeroom where only slow temperature variations occur a grade 1 would be used.

The size of fire to operate thermal detectors of differing sensitivity is given in Fig. 18(a) and (b).

These figures apply for a fire directly below the detector head. A fire situated a horizontal distance of six metres away from the head will need to be twice the size.

A reduction of sensitivity will also result if a strong air current is present or beams obstruct the flow of hot gases across the deck head.

In applying this first analysis, the approximate number and type of detectors necessary should be apparent. See Appendix IX for typical layout of detectors.

As a second check the effects of the following should be given consideration: —

(a) When the machinery deck head is high and when air currents are particularly strong, the coverage of high risk areas should be considered. Additional detectors may be necessary because of variations of air currents with engine power, and speed of ventilation fans. In some instances it may be desirable to move a detector in the direction the air flows rather than site it directly above the potential outbreak point.

(b) When the deck head has a deep web, as is common on some large tankers, the effects of stratification of air at the deck head can prevent smoke from a small fire getting to the detector (*see* Fig. 19(a)).

(c) Additional detectors may be fitted along the webs to detect smoke deflected by the heat barrier or infra-red heat detectors can be sited above the area protected (*see* Fig. 19(c)).

When installing detectors, a few metres of cable looped at each detector head will permit easy adjustment of position.

Thermal detectors are frequently proposed for control room protection, so that the operating staff can smoke without causing false alarms. Usually there is not sufficient combustible material available in a control room to set off a thermal detector. If combustion products detectors are set to a low level of sensitivity, it is possible to smoke in a control room without setting off the detectors, and still get adequate protection. The vapours given off by overheating electrical equipment prior to the outbreak of fire are more readily detected by light-scatter detectors, than by combustion products detectors. Therefore, control rooms containing main switchboard and electronic equipment will have better protection if light-scatter detectors are used. It would appear that the best results will be obtained if these are placed within the equipment or its ventilation system.

In completing this section it must be stressed that the best method of detecting, containing and extinguishing fire, in an engine room is to separate it into as many steel compartments as is practical. The location of the fire is more certain, and extinguishing it is easier.

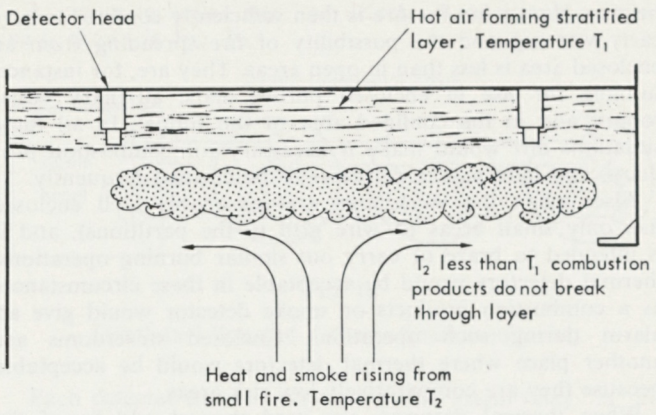


FIG. 19(a)

Detectors fail to be operated by small fire due to stratification.

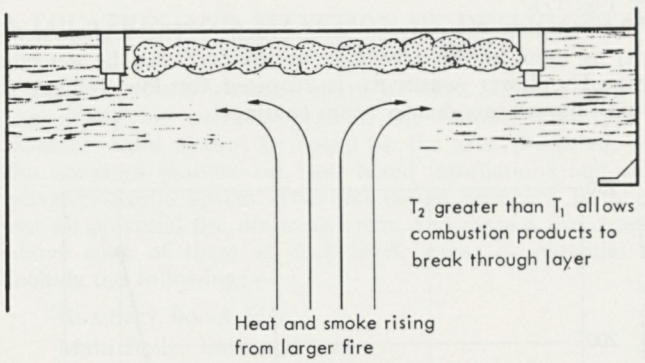


FIG. 19(b)

Detectors operated by larger fire.

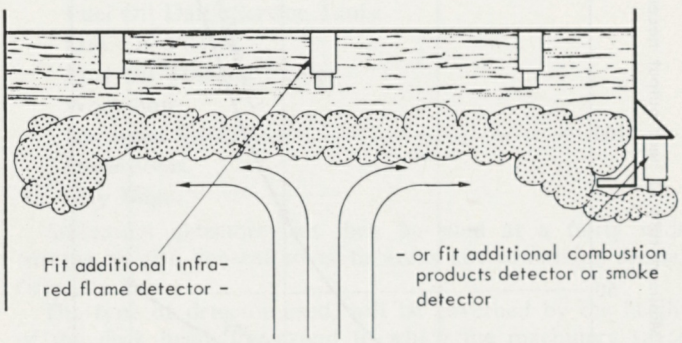


FIG. 19(c)

Methods of overcoming effect of stratification.

## 4. TESTING OF COMPLETED SYSTEMS

Comments on testing will be confined to operational checks.

The electrical survey and testing of the system should be treated in a similar manner to the rest of the electrical equipment of the ship. Detector heads should be disconnected when carrying out high voltage insulation measurements.

The operational tests will be considered in two parts:—

(a) Pre-trial testing.

(b) Trial testing.

(a) Before the vessel's trials, all the detector heads should be functionally tested.

For rate of rise detectors, this involves the application of heat with a suitable portable appliance. Some manufacturers use a small electrically heated muff, while others use an ordinary hot water bottle. For combustion products detectors a small butane burner is sometimes used as a rough check. As a check on the head itself, some manufacturers have a portable test set with which the sensitivity of the detector can be measured. The unit is unshipped from its mounting plug and inserted into the test set.

(b) **Trial Testing.** Tests should be carried out at sea with the main engines running, and in harbour with the main engines shut down. Generally, smoke and combustion products fire detectors, situated under low deckheads (i.e. less than three metres in height) will not present problems. A handful of cotton waste and 10 c.c. of diesel oil ignited in a bucket, adjacent to the potential fire hazard will generally operate the detector to prove correct siting.

Thermal detectors under low deck heads, however, cannot be made to operate with a test fire that would be acceptable in a ship. The small fire in a bucket suggested above, may be used to trace the direction of air currents to ensure that the ventilation system is not blowing cold air directly onto the detector or extracting heat rapidly up an exhaust trunk.

The test fire mentioned above should not be used in control rooms in which electronic equipment is housed. Electrical contacts carrying low power are easily contaminated by the deposits left by such a fire. It will usually be sufficient to limit tests to tracing air currents. One method of doing this is to use the type of smoke generator used for theatrical effects. An example is shown in Fig. 20.

A special type of vegetable oil is burnt at a controlled rate on a small enclosed electric hot plate and the combustion products are dispersed by a jet of carbon-dioxide from a pressurised cylinder. This smoke will not operate combustion products detectors unless the concentration is high, but it will operate light-scatter detectors recommended for protecting switchboards.

The most difficult problem of testing arises when the detectors are mounted at a high level. Smoke from a small enclosed bucket or from a smoke generator will not rise in the same way as smoke from a real fire. The air currents from engine intakes and ventilation fans are so strong that without the convection currents caused by the heat of a real fire, the smoke is scattered and a true test of the system is not achieved.

It is possible to use a test fire comprising a tray about 30 cm. square and 15 cm. high and burning a light-grade diesel oil vaporised on a layer of cotton waste in the bottom of the tray.

To use such a fire, small amounts of diesel oil should be tried initially and the quantity increased up to a maximum

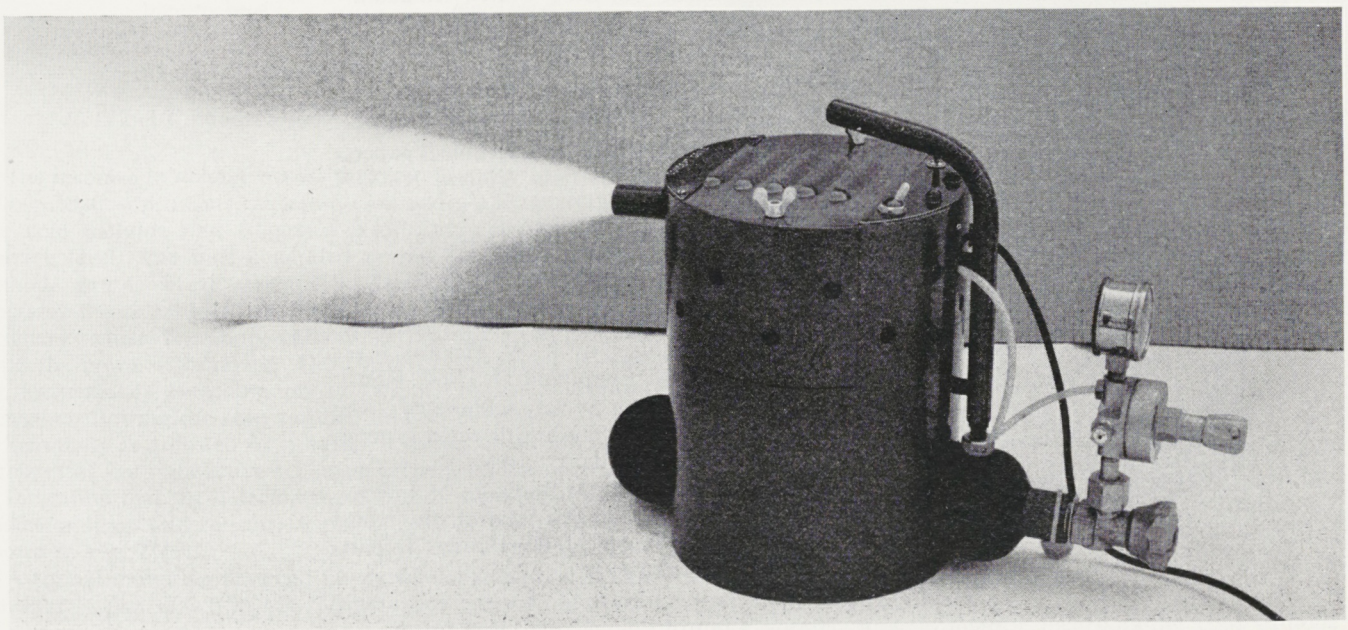

FIG. 20

Cosmetic Oil Smoke Generator.

limit of 250 c.c. or less than this if the risk of causing a real fire is considered possible.

While the Society will accept the results of such tests, the responsibility for testing the system in this way must rest on the detector manufacturer, the shipyard, and the owners.

The operation of infra-red heat detectors can be tested with a special portable flasher unit about the size of a hand torch. Units are available which will operate the detector from a distance of 15 metres. To ensure that the detector is not being affected by reflections from vibrating machinery, a portable detector may be used. Indication showing the level of response of the detector is provided in place of the normal triggering circuit.

## CONCLUDING REMARKS

This paper has endeavoured to give the state of the art of fire detection in unattended machinery spaces.

In the next few years we can look forward to the publication of more exact National and International Standards for all types of fire detectors.

This will provide an impetus to research into the deployment of detector heads. Hence it should be possible to convert this "art" into a "science". When this happens the Society should be in a position to define the size of fire to be detected in any given part of the machinery and the industry will be able to meet this requirement with a high level of confidence.


## ACKNOWLEDGEMENTS

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Graviner (Colnbrook) Ltd., United Kingdom.
The Walter Kidde Co. Ltd., United Kingdom.
L. & G. Fire Appliance Co. Ltd., United Kingdom.
Minerva Detector Co. Ltd., United Kingdom.
Pyrotector Europe GmbH, Germany.
The Pyrene Co. Ltd., United Kingdom.
Salen & Wicander AB, Sweden.



Reference has been made to the following technical papers:

The Institution of Fire Engineers Quarterly, Volume XXXIX, No. 71, September 1968.

Fire Detection Using Laser Beams, by D. I. Lawson, M.Sc., C.Eng., F.I.E.E., F.Inst.P., M.I.Fire.E.

The Institution of Fire Engineers Quarterly, Volume XXIV, No. 55, September 1964.

Gas Temperatures Beneath Ceilings, by R. W. Pickard, B.Sc., I.Inst.P., R. H. Bigmore, B.Sc.(Eng.), and D. Hind, B.Sc.



Thanks are due to many of the Society's Surveyors who have related their experiences in testing fire detector systems, in particular Ir. W. de Jong, Rotterdam.

The Author is also grateful to C. D. Sneddon, of International Conventions Dept., who has provided many useful references and G. Pumphrey, Technical Illustrations Department, who prepared the diagrams.

Finally, appreciation must be expressed for the encouragement of A. R. Hinson, Control Engineering Department.

# APPENDIX I

**Triggering Circuits for Combustion Products Detectors**

Fig. 21(i) shows a cold cathode tube triggering circuit.

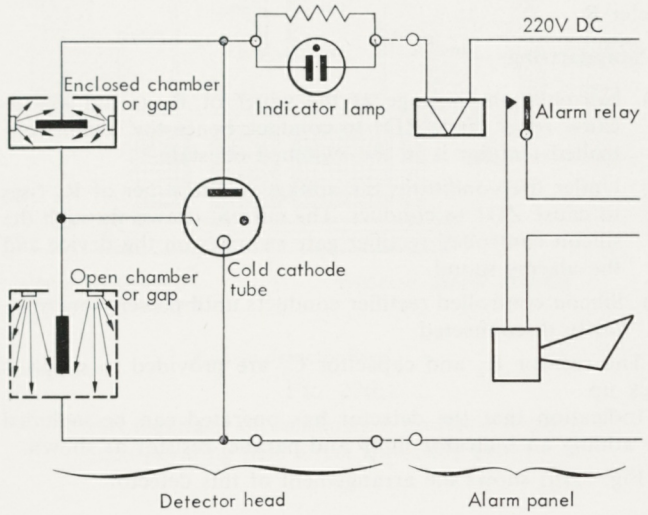



FIG. 21(i)

Cold Cathode Tube triggering Circuit.

The increase in voltage across the open gap due to presence of combustion products causes an electrical discharge between the cold cathode and trigger electrode at a predetermined voltage level. The ions generated permit the main anode—cathode gap to break down. The resulting flow of current operates the relay in a similar manner to the closing of an ordinary switch. The anode-cathode path continues to conduct until the power is removed. The alarm or zone relay is reset by momentarily switching off the supply to the relay and detector, allowing the cold cathode tube to de-ionize.

Sensitivity is adjusted by a variable shield which alters the strength of the radioactive radiation arriving at the open gap.

Indication that the detector has operated is provided by the indicator lamp and resistor. A photograph of this detector is shown in Fig. 21(ii).

A special mounting designed for marine applications of this detector is also shown in Fig. 21(iii).

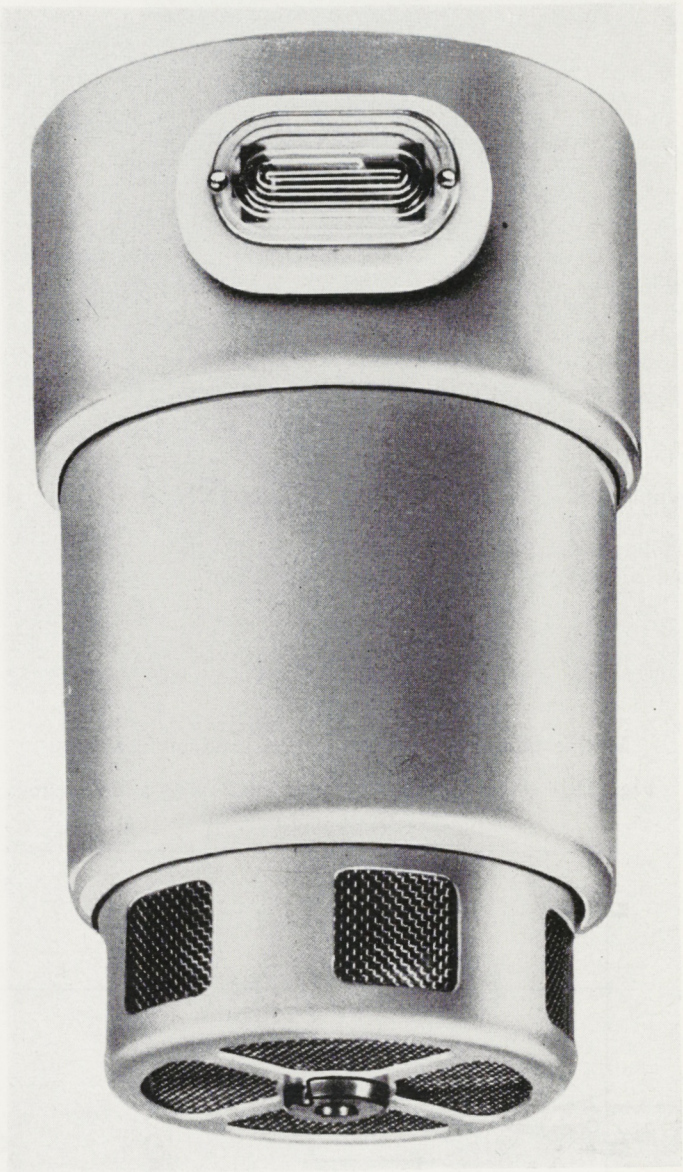


FIG. 21(ii)

Combustion products detector incorporating cold cathode tube.

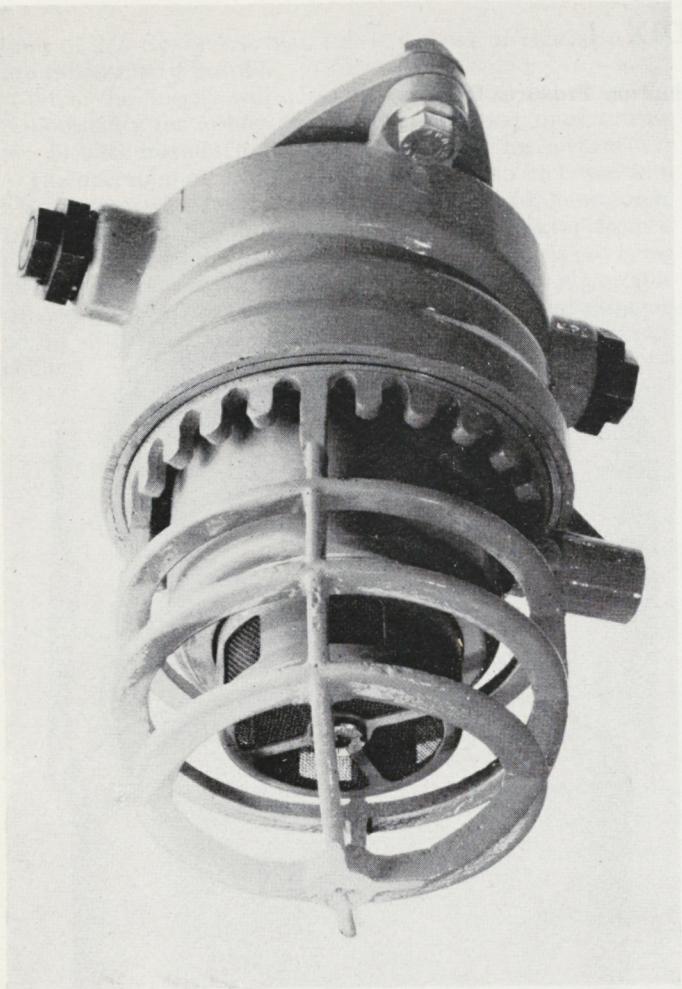


FIG. 21(iii)

Marine mounting for combustion products detector.

The voltage across the gaps or chambers is incapable of operating most types of semi-conductor devices because the current available is too small.

The field effect transistor, however, requires only a minute current in its gate circuit, and when used in the emitter follower configuration is suitable for detecting the signals involved.

The change in voltage due to the presence of combustion products appear across $R_1$ and the current available is sufficient to switch on the silicon controlled rectifier. This device operates in a similar manner to the cold cathode tube mentioned earlier. When a current is passed through the gate the current in the main conducting path is switched on and remains on until the power is momentarily removed.

Sensitivity is adjusted by means of the variable potentiometer $R_1$.

Summarizing: —

(a) Normally the voltage at the wiper of $R_1$ is too low to cause zener diode ZD1 to conduct, hence the silicon controlled rectifier is in the switched off state.

(b) Under fire conditions the voltage at the wiper of $R_1$ rises to cause ZD1 to conduct. The current drawn through the silicon controlled rectifier gate switches on the device and the alarms sound.

(c) Silicon controlled rectifier conducts until power is momentarily disconnected.

The resistor $R_2$ and capacitor $C_1$ are provided to suppress pick up.

Indication that the detector has operated can be included by adding an indicator lamp and parallel resistor as shown.

Fig. 22(ii) shows the arrangement of this detector.

Fig. 22(i) shows a trigger circuit employing a field effect transistor and a Silicon Controlled Rectifier.

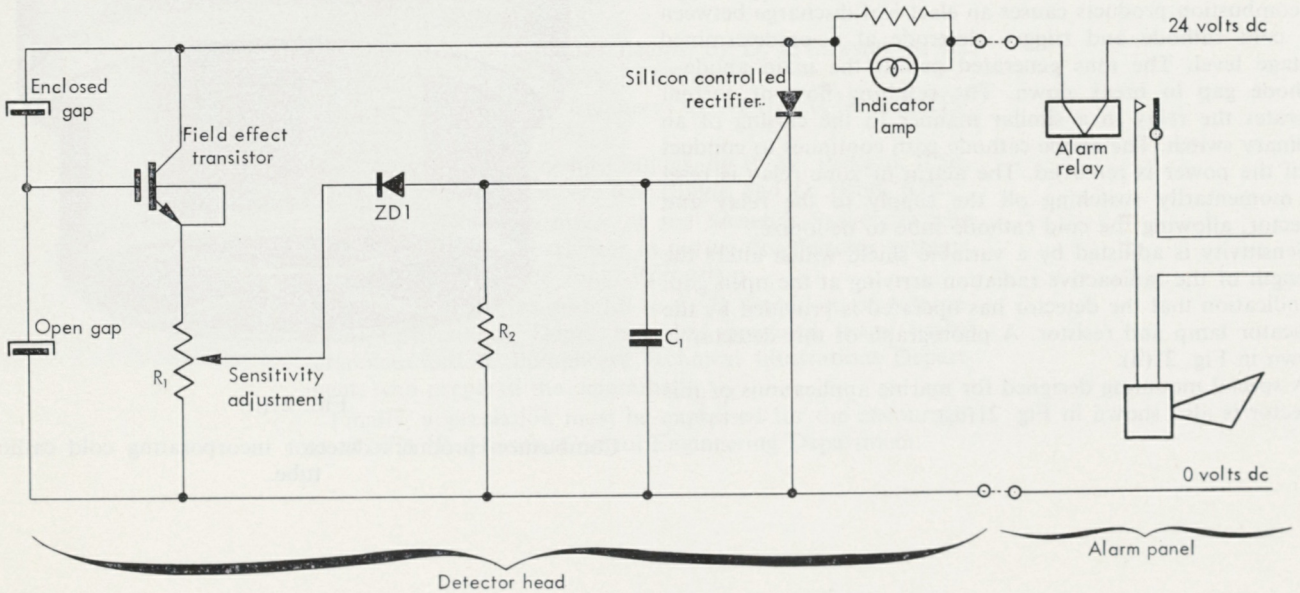



FIG. 22(i)

Field effect transistor and S.C.R. triggering circuit.

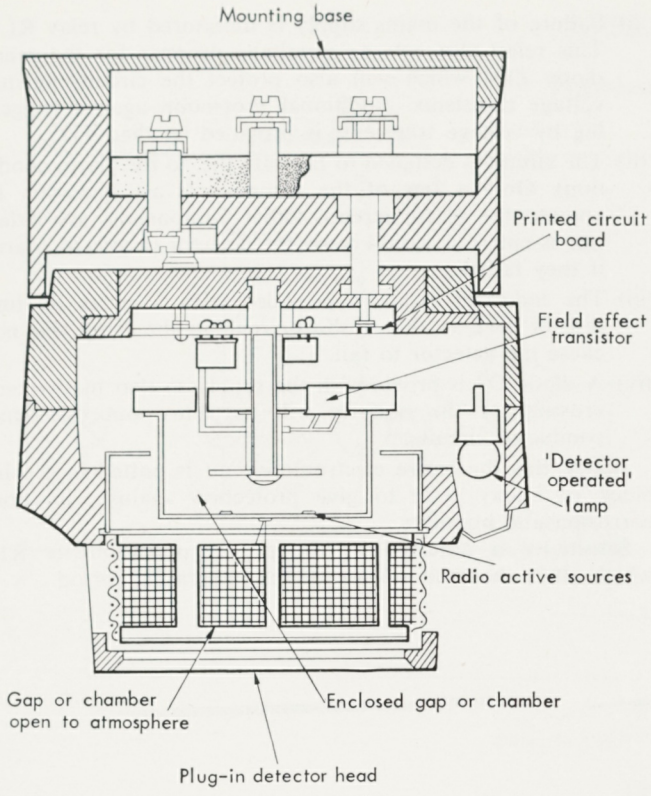



FIG. 22(ii)

Arrangement of combustion products detector incorporating field effect transistor and S.C.R.

Fig. 23 shows a circuit employing the integrating principle.

The irradiated gap passes a current which is reduced when combustion products are present. This current builds up a voltage on capacitor C2.

The circuits measure the voltage built up on this capacitor over a set time interval then it is discharged to allow the process to be repeated. When combustion products are present the voltage build-up on the capacitor is less than under normal conditions and the alarm is sounded.

The circuit can be broken down into three sections.

(A) The timing circuit which initiates the measurement of voltage across C2.

(B) The measuring circuit.

(C) The alarm initiating circuit.

Operation is as follows:—

**(A) Timing Circuit**

Capacitor C1 builds up a voltage at a rate determined by R1 and the pre-set potentiometers. The unijunction UJ1 conducts when the voltage on C1 reaches the firing voltage of the unijunction. Current flows through Relay RL1 and R2 causing the relay to operate. When C1 has discharged through the unijunction, the circuit de-energizes and the relay releases. The operation of the relay in this manner occurs momentarily about every 15 seconds.

**(B) Measuring Circuit**

While the voltage on the timing Capacitor C1 is building up periodically, a similar process occurs on capacitor C3.

However, the build-up of voltage is slower and normally does not reach a level which permits UJ3 to operate the fire alarm circuit.

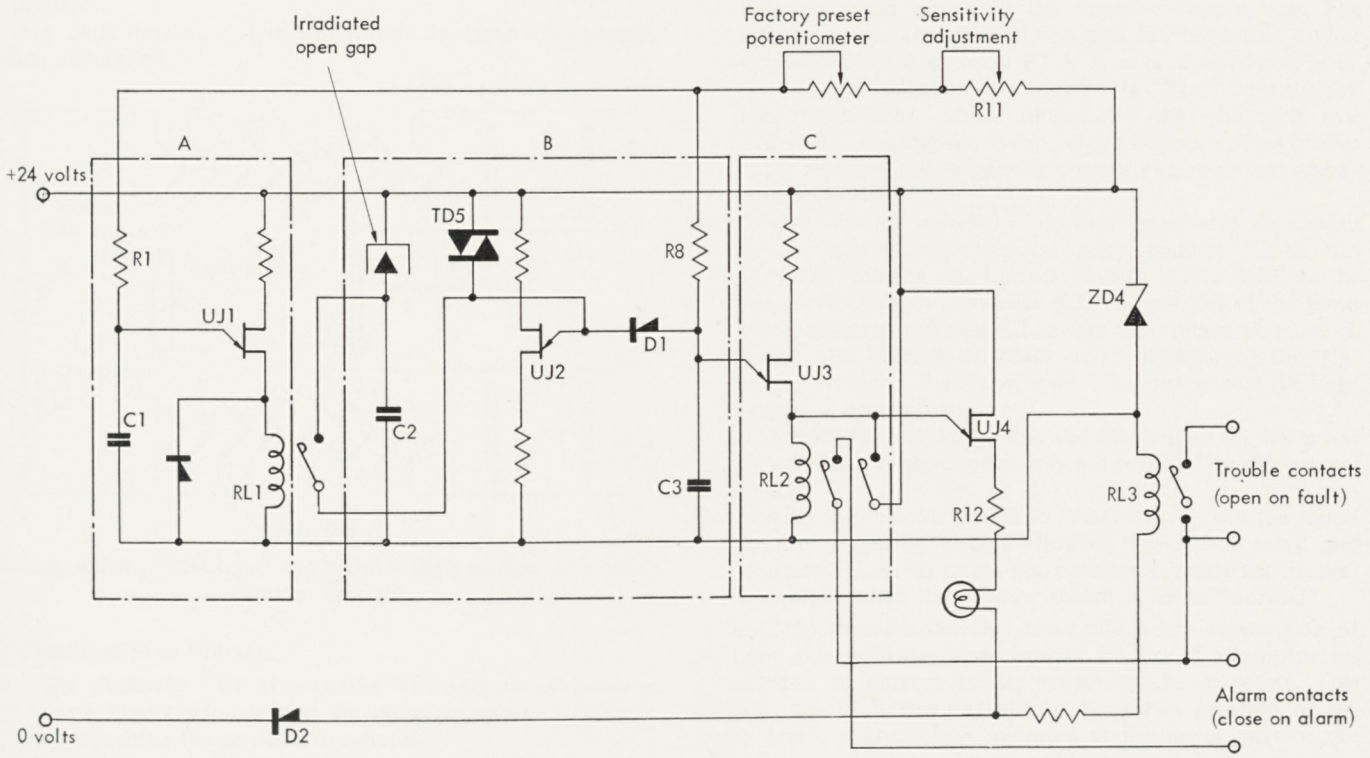



FIG. 23

Circuit of integrating combustion products detector.

When relay RL1 is operated by the timing circuit, the voltage on C3 discharges through diode D1 and the relay contacts to add to the voltage already present on C2.

If the voltage on C2 has built up to its normal level, the added voltage provided by C3 is sufficient to cause unijunction UJ2 to conduct causing C2 and C3 to discharge.

If the presence of combustion products cause the voltage on C2 to be low, the voltage added to it by C3 is not sufficient to cause UJ2 to conduct.

In consequence, the voltage remaining across C3 is not discharged during the measuring period by UJ2 and instead the voltage continues to build up causing UJ3 to conduct and operate the alarm relay RL2.

### (C) **Alarm Circuit**

When UJ3 operates relay RL2, one set of contacts initiate the alarm and the other set retain the relay in the operated state. UJ4 is operated from the voltage across RL2 and illuminates the "detector operated" indicator lamp.

The circuit includes many safety features.

(i) Failure of the mains supply is monitored by relay RL3. This relay also acts as a voltage dropper for the zener diode ZD4 which will also protect the circuits against voltage transients. Additional protection against triggering by voltage transients is provided by diac TD5.

(ii) The circuit is designed to fail safe (i.e. to the alarm condition). Only a few of the components are necessary to operate the alarm circuit. Other components are either not essential or would cause the detector to give an alarm if they failed.

(iii) The indicator lamp is provided with a series limiting resistor R12 so that a short-circuit in the lamp will not cause the detector to fail.

(iv) A diode D2 is provided in the supply so that inadvertent crossing of the polarity will not burn out the semiconductor circuits.

Beside this the entire electronic circuit is potted in a solid block of epoxy resin to give protection against vibration, corrosion and humidity.

Sensitivity is adjusted by the pre-set potentiometer R11 which alters the time interval of the integrating period.

# APPENDIX II

## Light-scatter Detectors

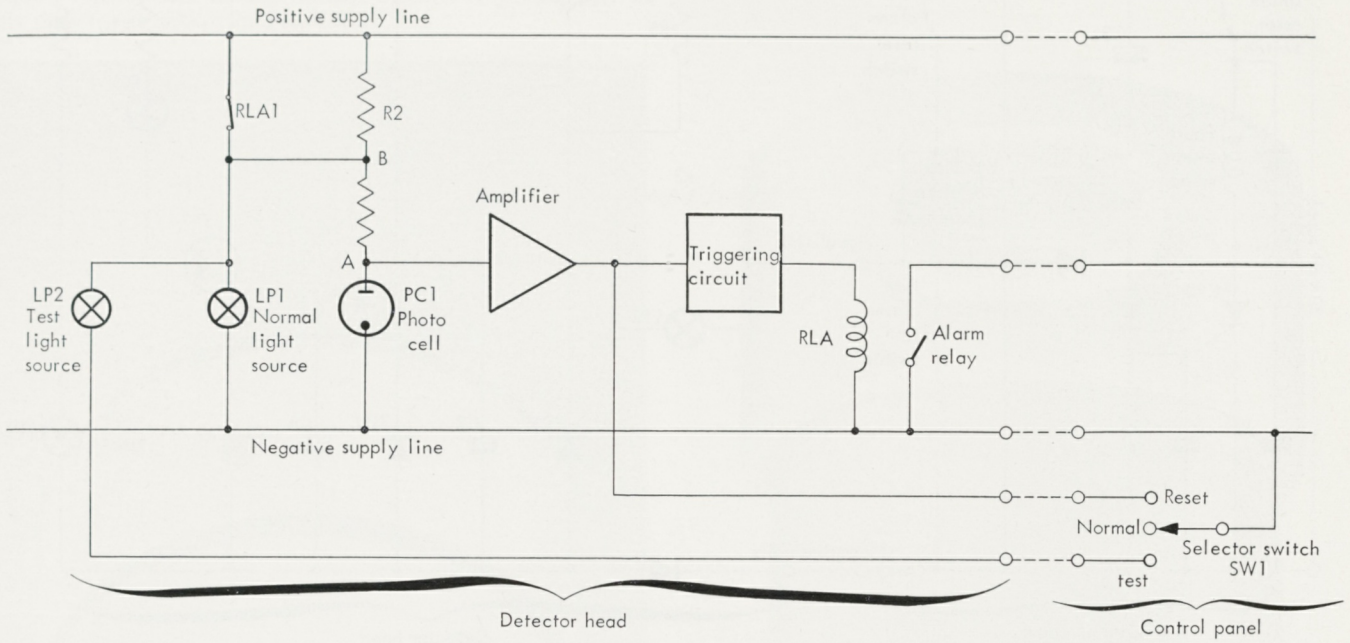



FIG. 24(i)

Test facilities for completely checking light scatter detector circuit.

It is desirable that Light-scatter Detectors have special provisions for ensuring that failure of the lamp does not go unnoticed.

Fig. 24(i) shows a system which tests the lamp and detector when demanded.

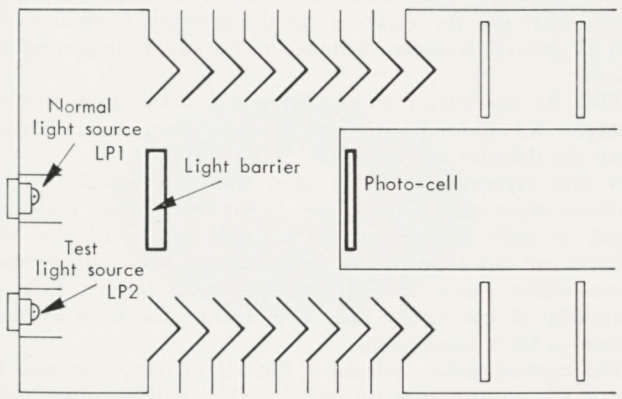



FIG. 24(ii)

Arrangement of test lamp and normal light source for a light-scatter detector.

Operation is as follows:—

(a) The photocell PC1 is normally not illuminated hence it has a high resistance and the voltage at point A is high, approaching the positive supply rail.
The triggering circuit senses this voltage after amplification and permits the alarm relay to remain de-energized.

(b) When smoke is present light is scattered onto PC1, its resistance is lowered and so the voltage at A moves downwards to approach the negative supply line. The change in voltage is amplified and the triggering circuit operates the alarm relay RLA at a predetermined level.

(c) Setting the selector switch SW1 to "test" operates an additional lamp which illuminates the photocell (*see* Fig. 24(ii)) causing the alarm relay to operate. This proves that the photocell, triggering circuit, and relay are operating properly.

(d) Setting selector switch to "normal" maintains the circuit in the alarm state because relay contact RLA1 has operated causing the normal lamp source LP1 to be energized through resistance R2. The current of the lamp being diverted through R2 lowers the voltage at point B, which also pulls down point A, so maintaining the triggering circuit in the alarm state. This proves that the light source is operational.
The operator will know that the filament in the lamp has failed if the alarm condition is not retained on the control panel.

(e) Setting the selector switch to "reset" shorts out the signal to the triggering circuit allowing the alarm relay and contacts RLA1 to reset. The detector is ready for normal operation when the selector switch is set to "normal".

Fig. 25(i) shows a detector head which has supervision of the light sources in the control panel. Failure of a lamp causes a reduction of current in the supply to the detectors. This operates the fault warning alarm. To aid in location of the faulty lamp, a green lens mounted at the lower part of the detector which is also illuminated by the light source (*see* Fig. 25(ii)).

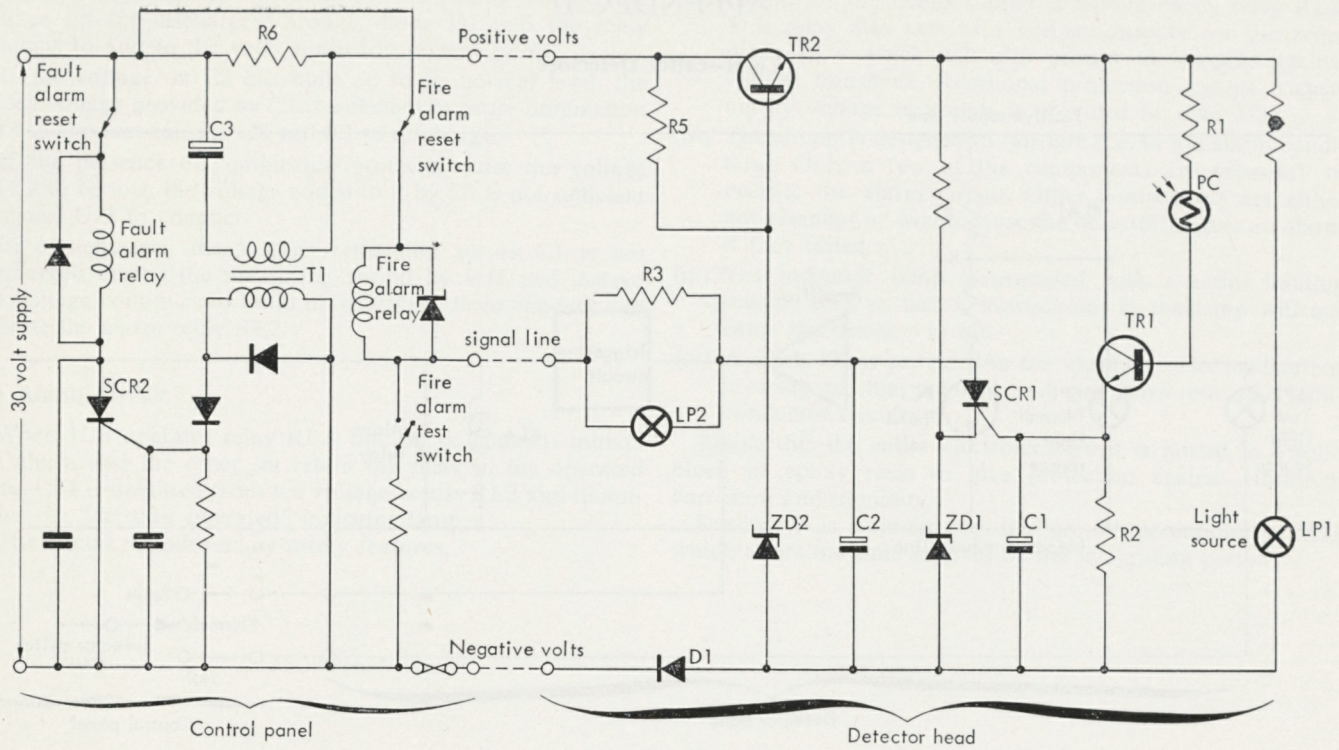



FIG. 25(i)

Circuit of light-scatter detector with continuous monitoring of lamp.

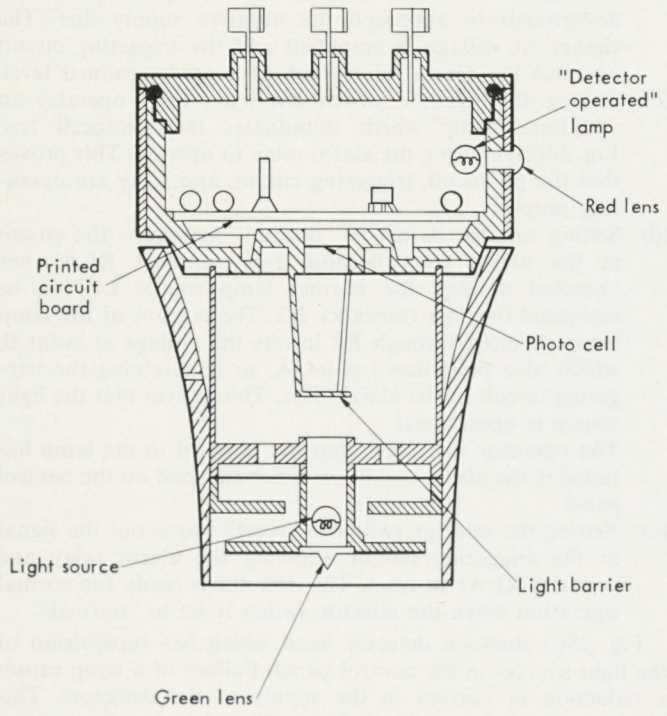



FIG. 25(ii)

General arrangements of light-scatter detector.

Operation of this detector may be described as follows with reference to Fig. 25(i). TR1 amplifies the output current of the photo-resistive cell PC1, and SCR1 is switched on when the voltage across R2 reaches a predetermined voltage set by ZD1. The voltage across R2 will correspond to the amount of smoke scattering light onto the photocell from the lamp LP1. Hence ZD1 sets the sensitivity of the detector. Capacitors C1 and C2 prevent transient voltages on the supply triggering the circuit.

TR2, R5 and ZD2 regulates the power supply to a constant voltage; R3 and LP2 provide a series energized indication when the detector has operated.

A line supervisory unit is used with this detector which operates when continuity of the signal line is lost. This unit, which is built into the detector head at end of the line, switches off the light source and operates the fault warning alarm which reacts to the apparent lamp failure. Loss of continuity of the supply lines also operate the fault warning system as for a lamp failure.

The control panel includes a fire alarm relay operated by the SCR's in the detector heads. The fault warning relay which senses lamp failures and line faults is operated by the variation in volt drop across R6 due to change of current. This change passes through capacitor C3 and transformer T1 to provide a triggering voltage for SCR2, which operates the fault alarm relay. An open circuit on the supply lines causes a reduction in current which operates the fault relay. A short circuit on the supply lines ruptures the fuse in the negative line and the reduction of line current operates the fault relay.

A rectifier D1 is included in the supply line to avoid damage if the detector supply connections are accidentally crossed during installation.

Although filament failure is monitored in this detector, the lamp is of specially rugged design and is operated well below its normal rating. It is to be expected that lamps would not require replacement during normal service. A photograph of this detector is shown in Fig. 25(iii).

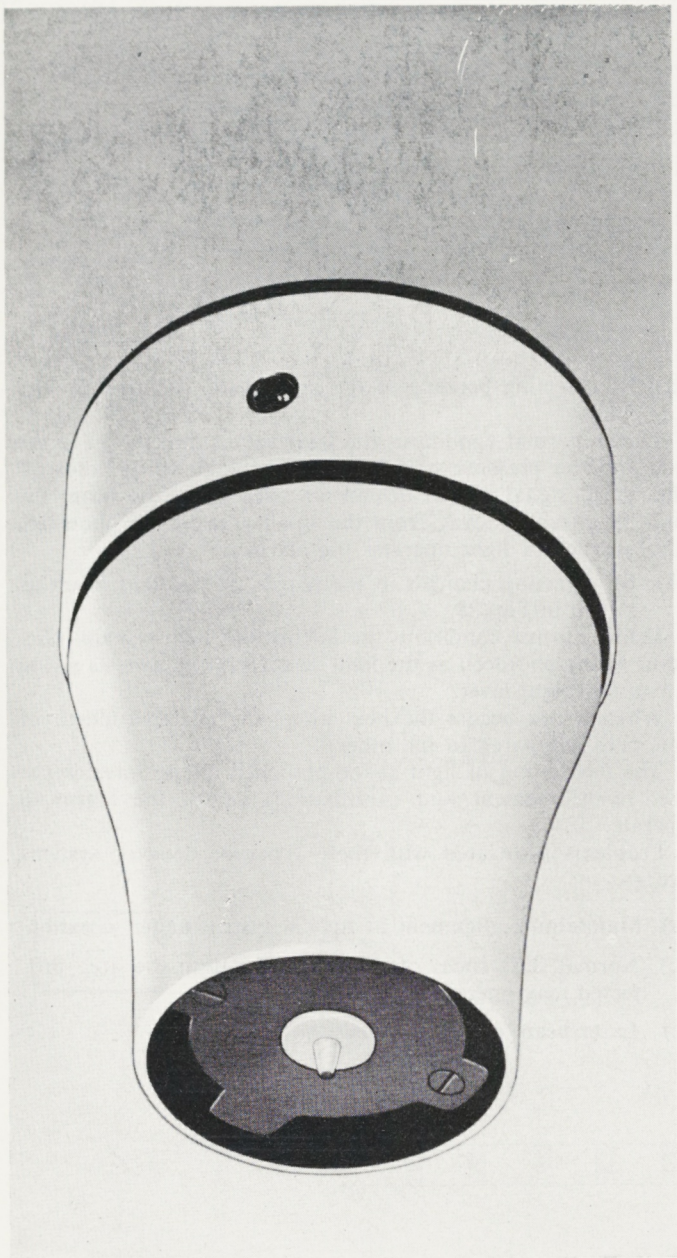


FIG. 25(iii)

Light-scatter smoke detector.

Fig. 26 shows a detector which uses an xenon flash tube instead of a filament lamp.

As has already been mentioned filament lamps of suitable construction and operated at reduced voltage have a very low failure rate. Use of a robustly constructed flash tube will reduce this failure rate to a lower level.

This particular detector uses a cold cathode tube trigger device similar to that shown in Appendix I Fig. 21(i) and is directly interchangeable with this detector which has an identical mounting base.

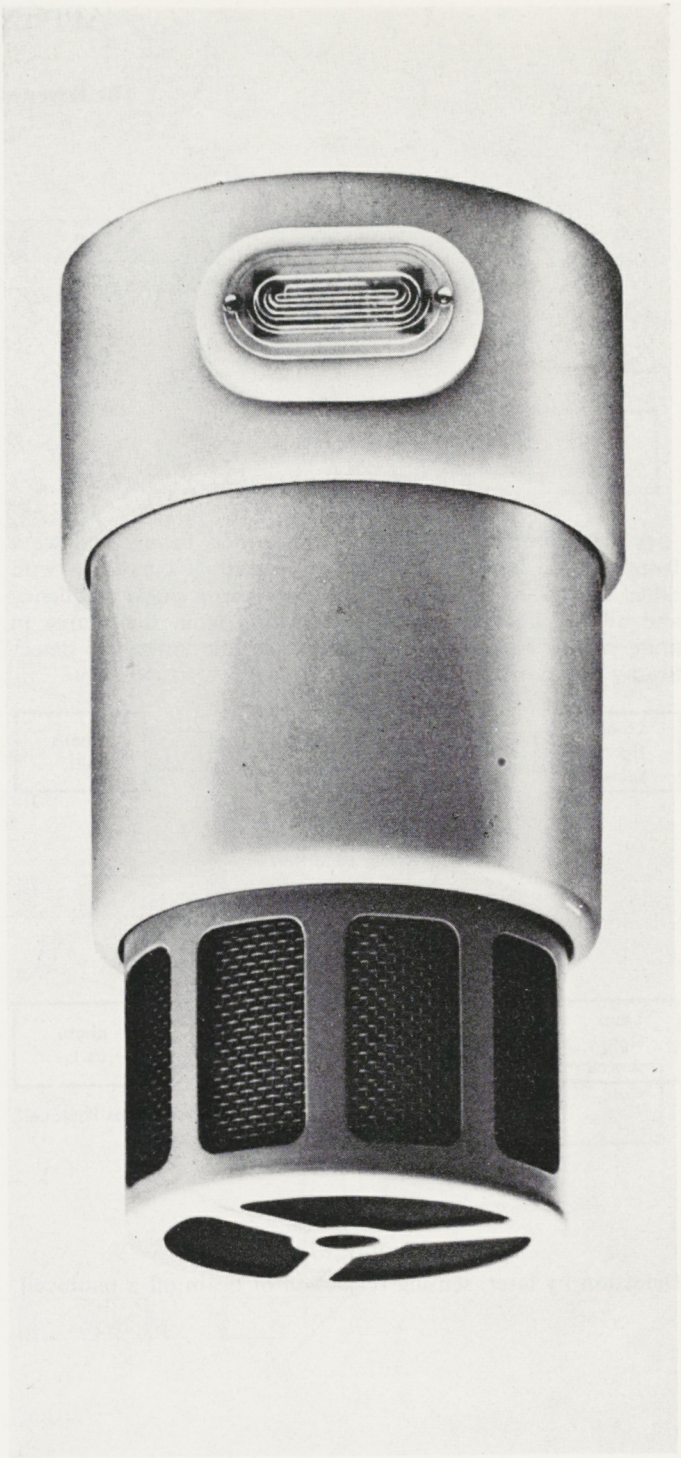


FIG. 26

Light-scatter smoke detector incorporating flash tube light source.

The flash tube produces a brilliant pulse of light of very short duration once every $2\frac{1}{2}$ seconds, and has an estimated life of ten years.

# APPENDIX III

**The laser used to detect fire**

A laser produces light in a thin pencil beam. The wave fronts of the light waves are flat, instead of curved as with other sources of light. Also, the light is one single frequency and all the light emanated is pulsating from the source in finite waves. These special properties can be utilized to detect fire by two possible arrangements: —

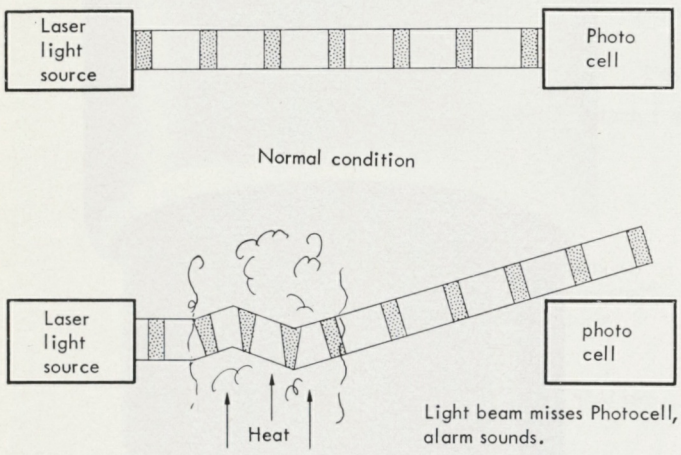



FIG. 27

Detection by laser, sensing refraction of beam off a photocell.

(a) By detecting bending of the light beam as shown in Fig. 27.

Under normal conditions the laser shines directly on to the cell and the presence of light gives a signal which holds off the alarm signal. When heated air rises along the beam the light is refracted away from the small area of the photocell, and absence of light operates the alarm.

(b) By detecting changes in the length of the light beam as shown in Fig. 28.

Under normal conditions the intensity of light remains constant at the photocell as the light re-enforces or cancels giving a constant light level.

When a fire occurs the heat alters the effective length of one path compared to the other.

The fluctuation of light at the photocell due to interference (i.e. re-enforcement and cancellation) causes the alarm to operate.

Problems associated with these types of detector systems are: —

(a) Maintaining alignment of optical system under vibration.

(b) Normal differences of temperature within the area protected may operate the alarm.

(c) Laser beam can damage eyesight.

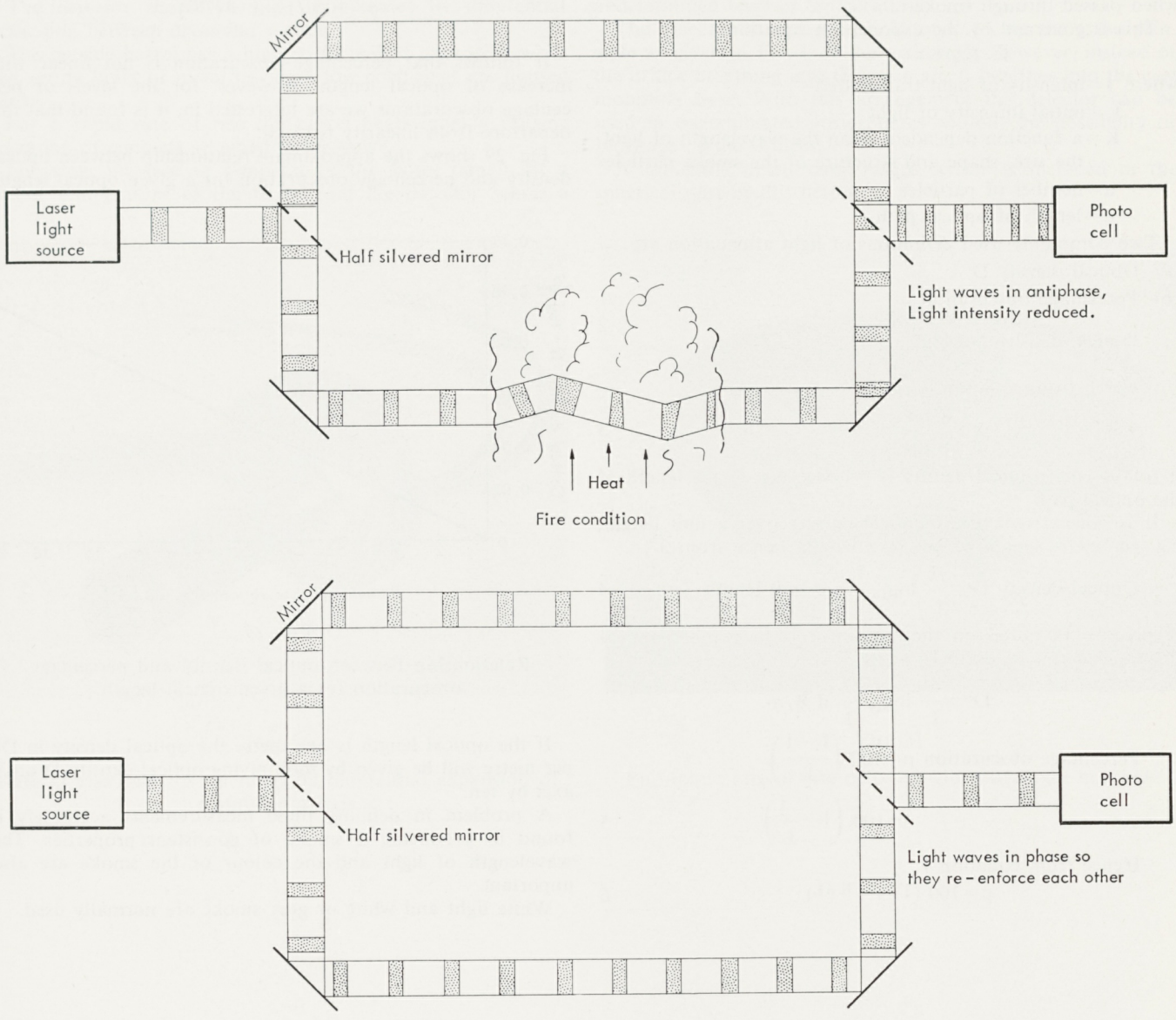



FIG. 28

Detection by laser, sensing interference of two beams at photocell.

# APPENDIX IV

**Definition of performance of smoke detectors**

Laboratory methods rely on the attenuation of a light beam when passed through smoke.

This is governed by the exponential equation

$$I = I_o e^{-K n L} \qquad 1$$

where I = intensity of light transmitted

$I_o$ = initial intensity of light

K = a function dependent upon the wavelength of light, the size, shape and structure of the smoke particles

n = number of particles

L = length of optical path

Two commonly used definitions of light attenuation are:—

(a) Optical density D

(b) Percentage obscuration p

$$\text{Optical density } D = \log_{10} \frac{I_o}{I} \qquad 2$$

which from equation (1) gives

$$D = \frac{K n L}{2 \cdot 303} \qquad 3$$

it follows that optical density is proportional to the length of the optical path.

It is normal to express optical density over a unit length, e.g. per metre length or per foot length, hence from 3

$$\text{Optical density } D' = \frac{I}{L} \log_{10} \frac{I_o}{I} \text{ per unit length} \qquad 4$$

A practise favoured on the Continent is to express optical density in terms of decibels/metre

$$D'' = \frac{10}{L} \log_{10} \frac{I_o}{I} \text{ d B/m}$$

$$\text{Percentage obscuration } p = 100 \left( \frac{I_o - I}{I_o} \right)$$

$$= 100 \left( 1 - \frac{I}{I_o} \right) \qquad 5$$

Hence from equation 1

$$p = 100 \, (1 - e^{-K n L}) \qquad 6$$

and from equation 3

$$p = 100 \, (1 - e^{-2 \cdot 303 D}) \qquad 7$$

It follows that percentage obscuration is not linear with increase of optical length. However, for the levels of percentage obscurations we are interested in, it is found that this departure from linearity is small.

Fig. 29 shows the approximate relationship between optical density and percentage obscuration for a given optical length.

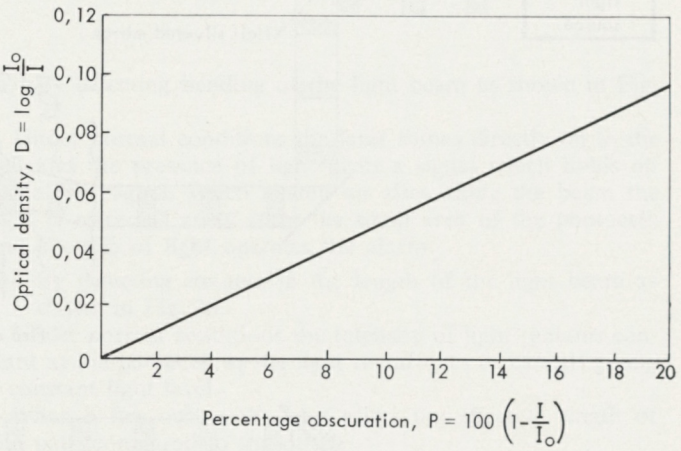



FIG. 29

Relationship between optical density and percentage obscuration for a given optical length.

If the optical length is one metre the optical density in Db per metre will be given by multiplying optical density D on Y axis by ten.

A problem in defining these measurements accurately is found in producing a smoke of consistent properties. The wavelength of light and the colour of the smoke are also important.

White light and white or grey smoke are normally used.

# APPENDIX V

**Examples of rate of rise detectors**

The detector shown in Fig. 30 operates by differential expansion between dissimilar metals.

The outside barrel has a high coefficient of expansion while two spring bows of metal having a low coefficient are housed inside.

For a rapid rate of rise the barrel heats quickly causing operation of contacts attached to the bows.

For slow increase in temperature the bows remain at a similar temperature to the barrel and the detector senses a predetermined level of temperature.

The detector shown in Fig. 31 operates on the same principle as given in Fig. 6 of the main text. However, instead of the orifice breathing into the open air, it breathes into the cast mounting base. With this arrangement the detector can be used in contaminated atmospheres without the possibility of blockage of the orifices.

A bimetallic fixed temperature sensor is included in the spherical part of this detector.

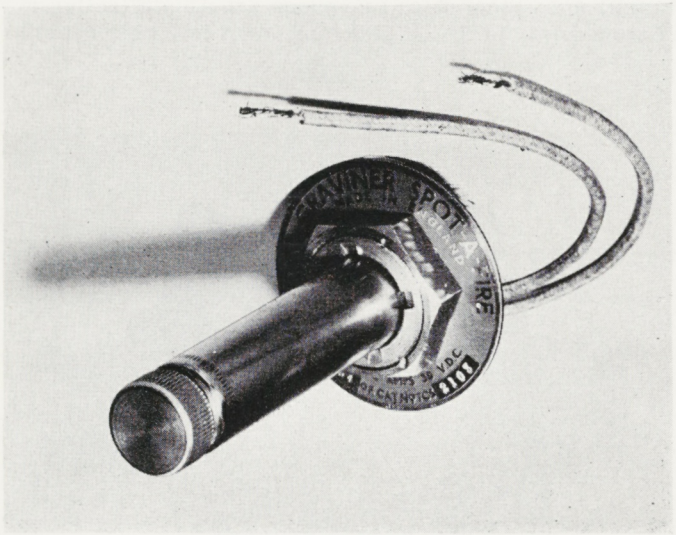



FIG. 30

Rate of rise detector operated by differential expansion of dissimilar metals.

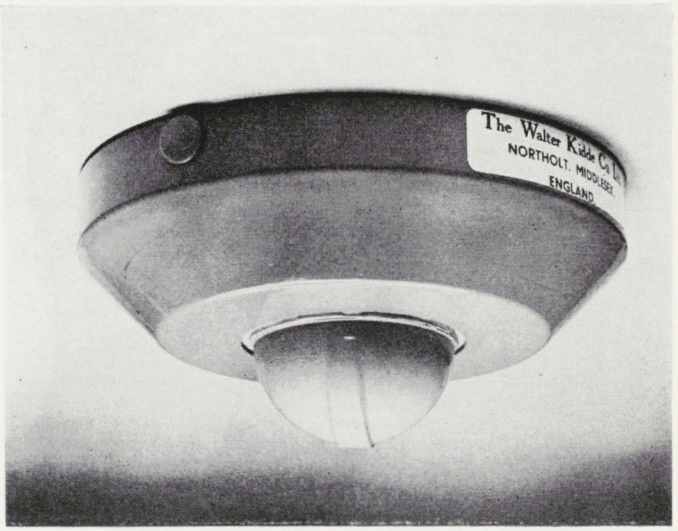



FIG. 31

Pneumatic rate of rise detector with watertight housing.

# APPENDIX VI

**Examples of Fixed Temperature Detectors**

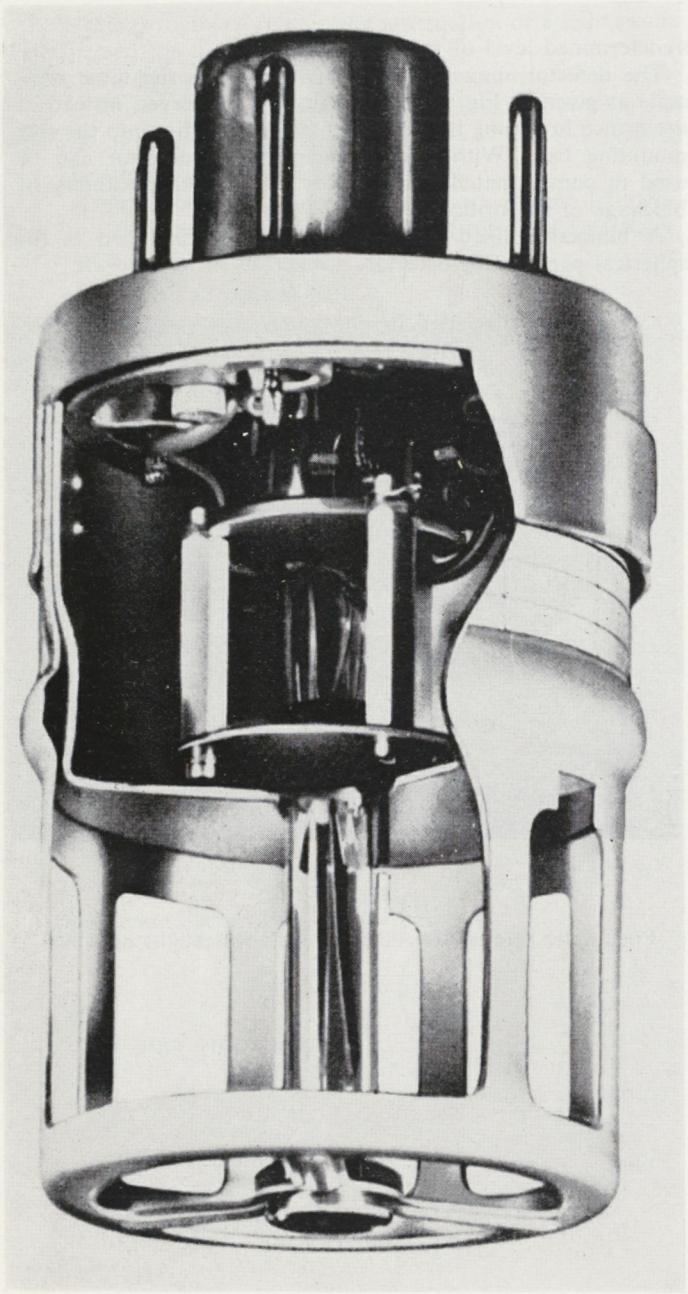


FIG. 32

Fixed temperature detector operated by a bimetallic contact assembly sealed into a glass tube.

Fig. 32 shows a detector operated by bimetallic contacts sealed inside a glass tube. This avoids contamination of the contacts by dust or corrosive atmospheres.

Fig. 33 shows a detector operated by the change of resistance of a thermistor connected to an electronic sensor.

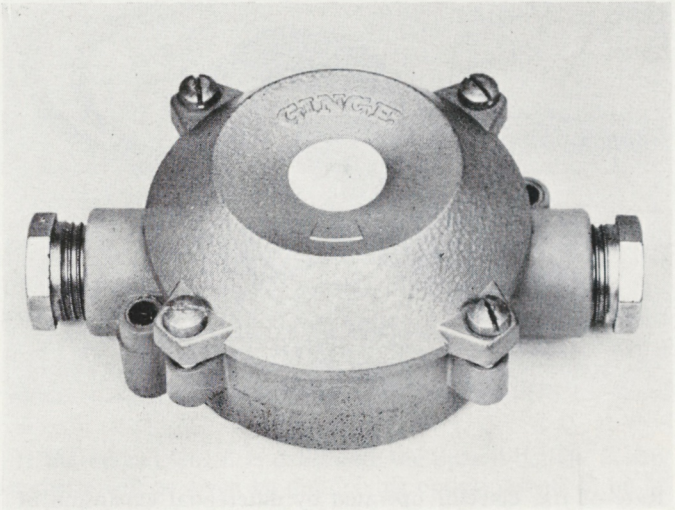


FIG. 33

Thermistor fixed temperature detector.

# APPENDIX VII

## Control Panel Circuits

Fig. 34 shows arrangements for automatically switching from mains to battery supply.

Relay A drops out when the mains fail. Contacts A1 and A2 open disconnecting the normal supply, contacts A3 and A4 close connecting the battery.

The battery is maintained in a charged condition by the zener diode chain. If the battery voltage is low the current will flow into the battery. When fully charged the voltage rise across the battery will cause the zener diodes to conduct preventing over-charge of the battery.

The circuit of a loop monitoring control panel with five zones is shown in Fig. 35 ; under normal conditions relay V is energized through the continuous cable loops connecting the fire detectors and relay, RLAA to RLAE are de-energized as shown in Fig. 35(i). When a fire operates a detector head the contacts short-circuits relay RLV causing it to release. (Resistor R1 limits current through short-circuit.)

The change-over of relay RLV contacts V1 to V5 permits the appropriate zone alarm relay to be energized. This operates the alarms and causes the zone indicator lamp ILA to be illuminated as shown in Fig. 35(ii). The fire/fault lamp ILS is also illuminated by closing of contacts V6.

When an open-circuit fault occurs on the cables, relay RLV de-energizes and releases (as shown in Fig. 35(iii)). This illuminates the fire/fault lamp ILS and operates the fault alarm through additional contacts on relay V and normally closed contacts on the zone relays not shown.

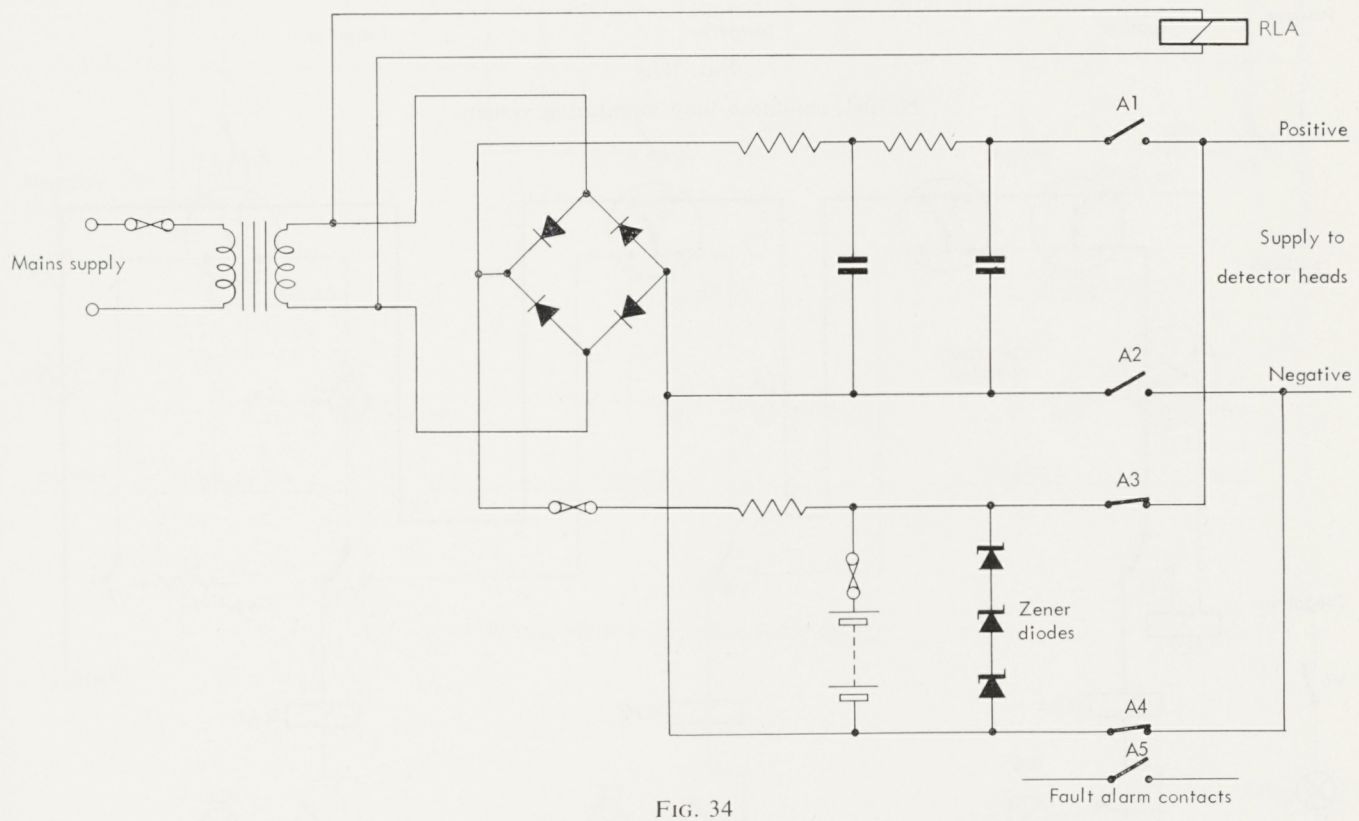



FIG. 34

Mains to battery automatic changeover circuit.

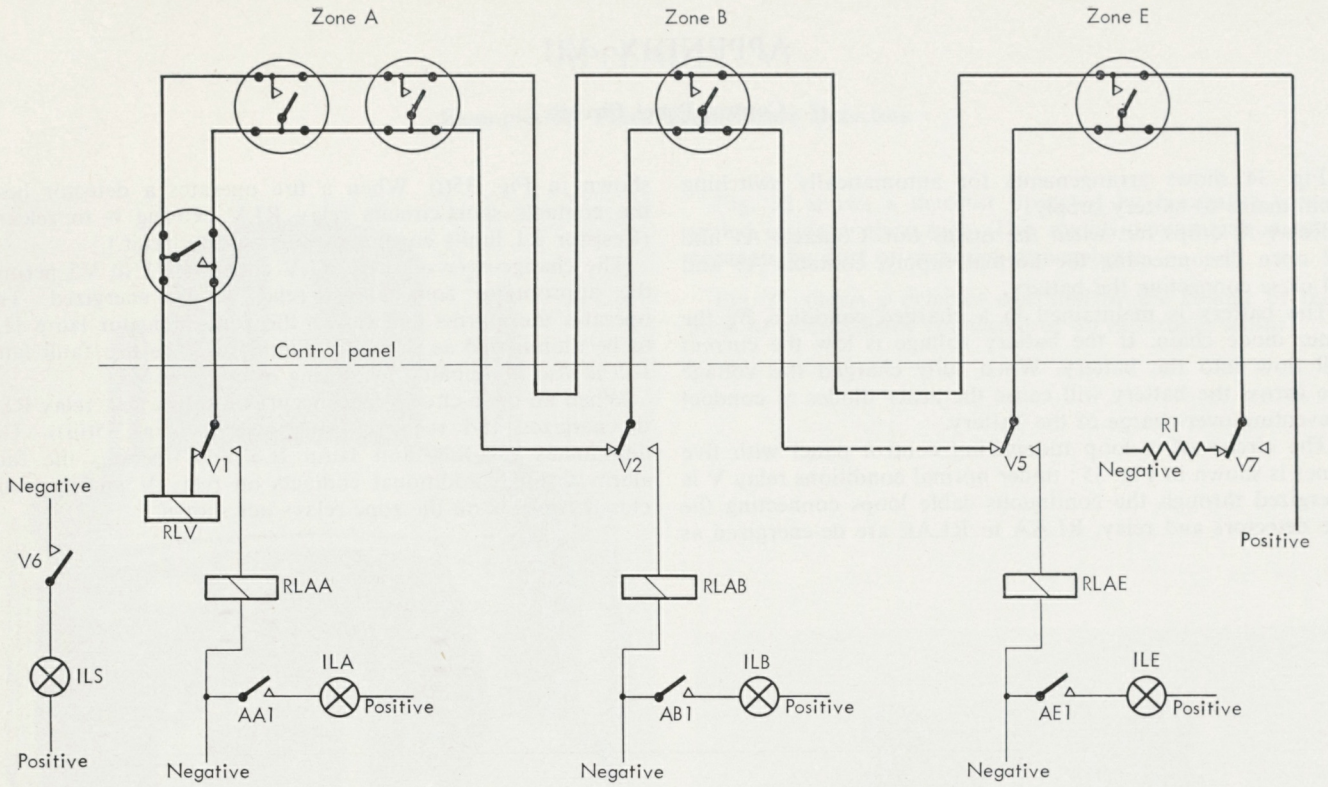



FIG. 35(i)

Normal condition loop monitoring system.

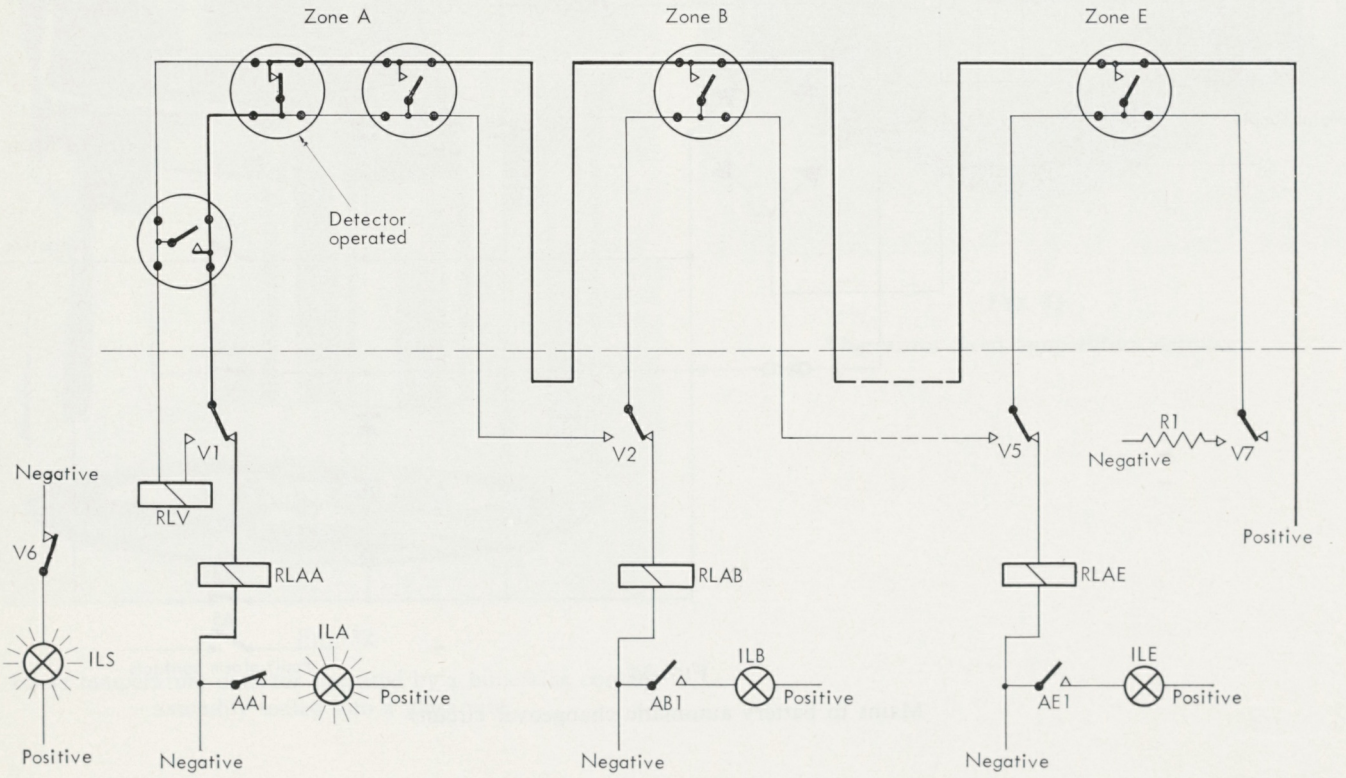



FIG. 35 (ii)

Fine condition loop monitoring system.

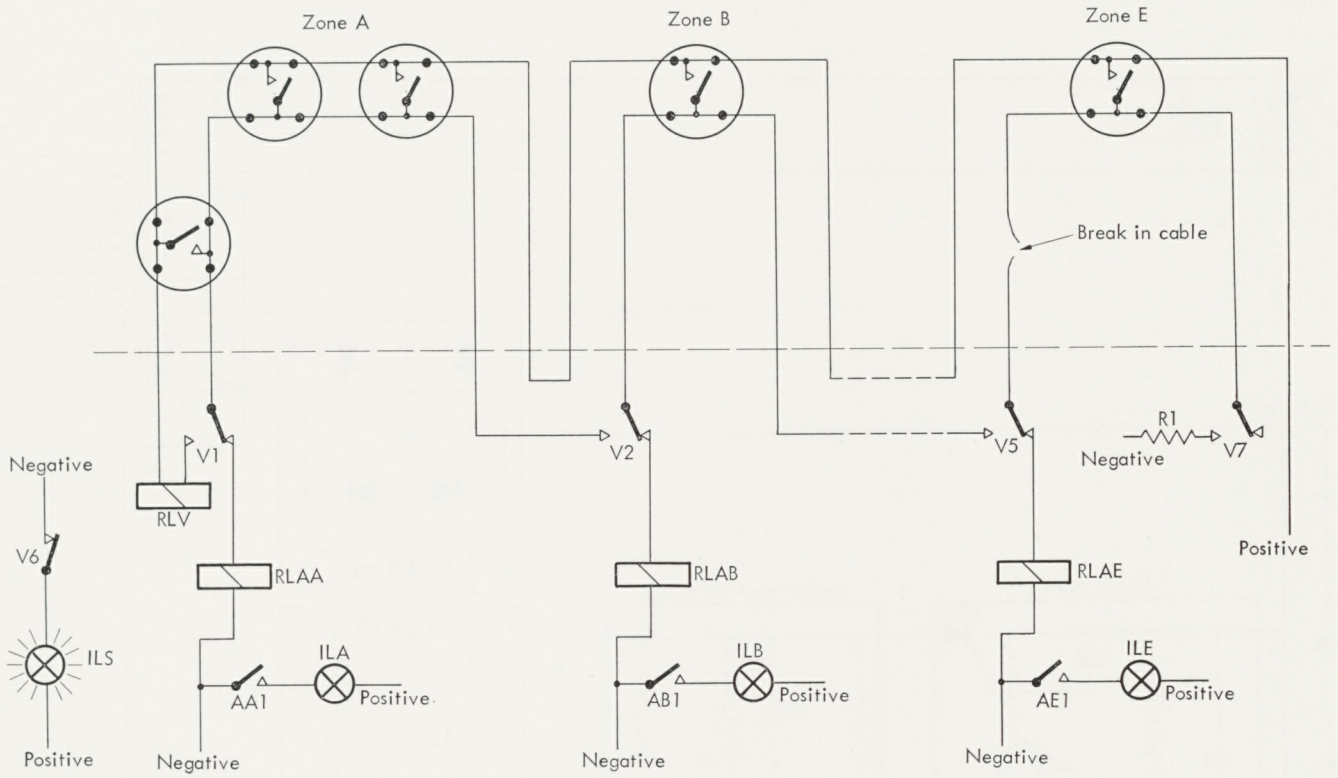



FIG. 35(iii)

Wiring fault loop monitoring system.

# APPENDIX VIII

## Inverter Circuit

The inverter shown in Fig. 36 is used to convert a low voltage battery output into an alternating voltage at mains potential.

When the unit is operating on the mains supply, relay 2 is energized, closing contacts 2(a), and opening 2(b), 2(c) and 2(d). The detector control panel is powered through the upper winding of the transformer primary.

Upon mains failure relay 2 is de-energized. This causes contact 2(a) to open, disconnecting the mains from the transformer and contacts 2(b), 2(c) and 2(d) close preparing the inverter for operation.

Contact 2(d) energizes the delay unit which switches on SCR1 after a suitable delay. This connects the supply to the square wave generator and the pulse transformer drive circuit which generate the alternating voltage.

The delay unit is necessary to avoid switching transients from the transformer as the flux collapses.

The alternating voltage waveform is generated initially by the square wave generator. This is a standard multivibrator circuit in which the transistors T1 and T2 are alternately switched from the conducting to the non-conducting state by the charging and discharge of C1 and C2 by R1 and R2.

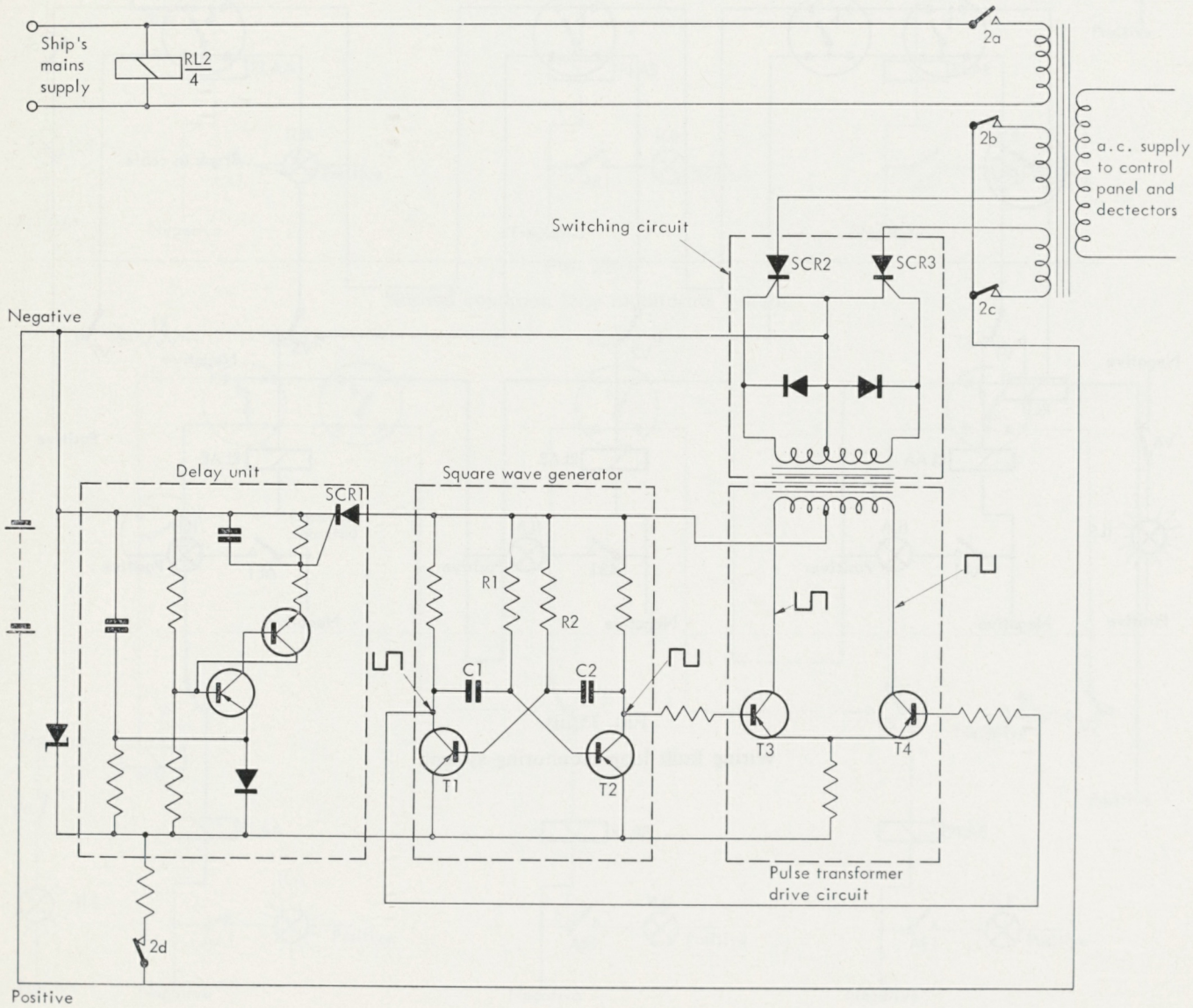



FIG. 36

Circuit diagram of inverter.

The square waves generated at the collectors of T1 and T2 are in antiphase to one another.

These voltages alternately switch on transistors T3 and T4 in the pulse transformer drive circuit. The pulses produced by the changing flux as the transistors T3 and T4 change over, cause voltage spikes at the gates of the SCR's 2 and 3 which also conduct alternately.

Because these SCR's are connected directly to the battery through the two lower primary windings, connected in opposition an alternating voltage is induced in the secondary winding supplying the detector heads.

Although SCR's 2 and 3 are connected to a direct current supply, the SCR which is conducted is able to switch off when the other is switched on as the latter produces a voltage of reversed polarity in the primary winding of the transformer at the moment of switch on. This voltage reversal allows current in previously conducting SCR to fall to zero permitting it to switch off.

# APPENDIX IX

**Layout of detectors in machinery space**

Fig. 37 shows the layout of the engine of a fairly small ship.

Detectors 1 and 2 are protecting the generator sets and could be either combustion products or smoke detectors.

They are placed slightly outboard of the generators in order to give additional cover to the surrounding area. It will be seen that they are fairly equally spaced across the breadth of the deck head.

Detector 3 protects the control room. A combustion products smoke detector or a rate of rise detector could be used in this position as it is an enclosed area. The first two are preferable, the smoke detector especially so, if electronic equipment is installed.

Detector 4 protects the boiler and the air compressors. By siting the detector near the boiler burners but towards the casing, quite adequate protection is afforded to this area.

On a larger vessel additional detectors would be required. Generally combustion products or smoke detectors would be used in this position. An additional infra-red flame could be justified on the grounds of the high risk of fire at the boiler front.

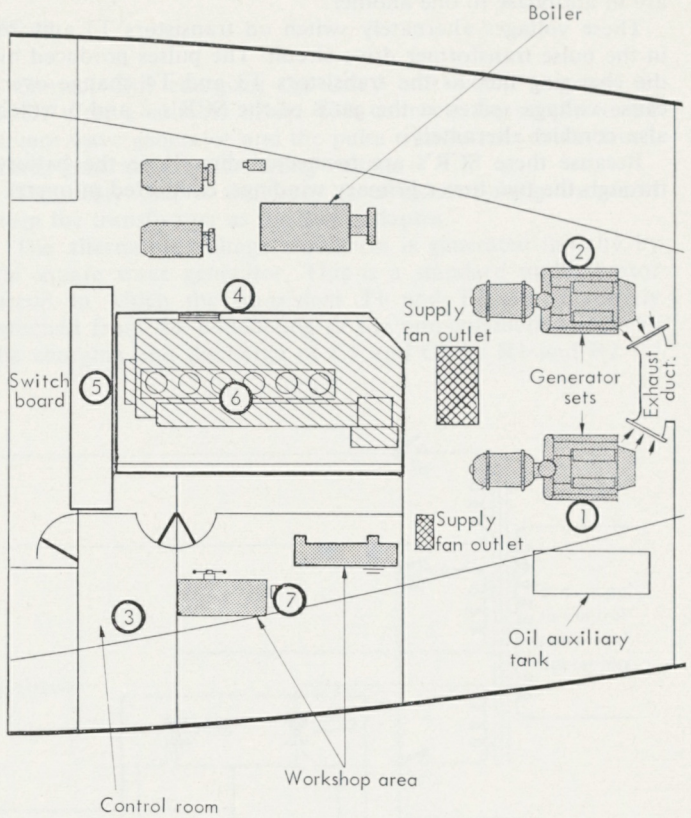
Detector 5 protects the switchboard. A combustion products or smoke detector would be used in this position. Again a slight advantage is gained by using the smoke detector.

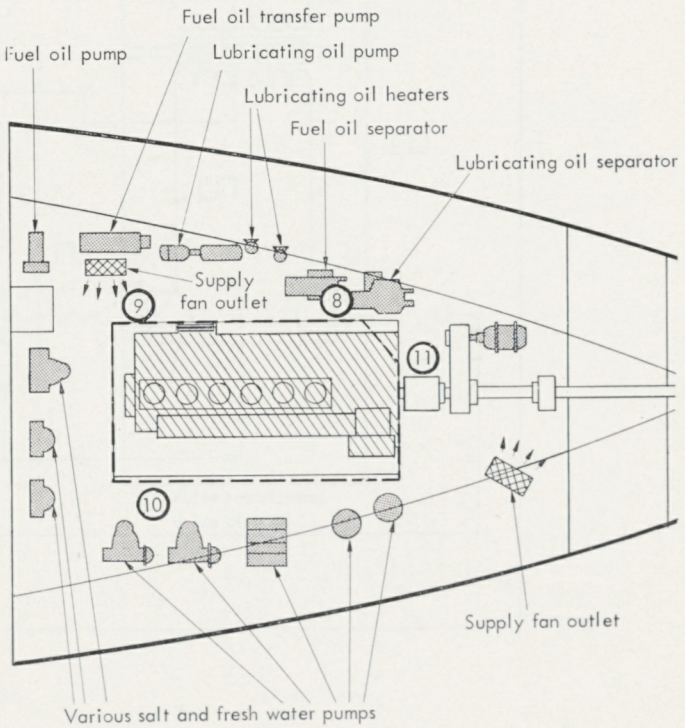
Detector 6 gives protection to cylinder heads. On a large vessel additional detectors would be required. Combustion products or smoke detectors would be used in this position. Additional overall cover would be afforded by adding an infra-red flame detector.

Detector 7 protects the workshop area, a combustion product, smoke or rate of rise detector could be used. If burning of any kind is to be carried out in this space a rate of rise detector is preferred if the area is adequately enclosed. Detectors 8, 9, 10 and 11 give protection to the various pumps and auxiliaries on the lower flat. These are placed near the edge of the aperture in the 'tween deck on a vessel of this size because convection will cause air to flow up towards the casing. A larger number of detectors are placed on the starboard side as all the likely fire hazards are situated there. Combustion products or smoke detectors would be used. In very large tankers an infra-red flame detector could be considered to augment protection, if the height justifies it.

Detector 12. This protects against soot fires in the funnel or possible fire in the fuel tank mounted high in the machinery. Combustion products or smoke detectors could be used. If a suitable flat unventilated area is available at the top of the funnel a rate of rise or fixed temperature detector could be used in this situation.

Trouble could be experienced with a combustion products detector if exhaust gases tend to eddy into the ventilator under certain weather conditions, e.g. a light following wind. A smoke detector would be less prone to false alarm, in this situation.



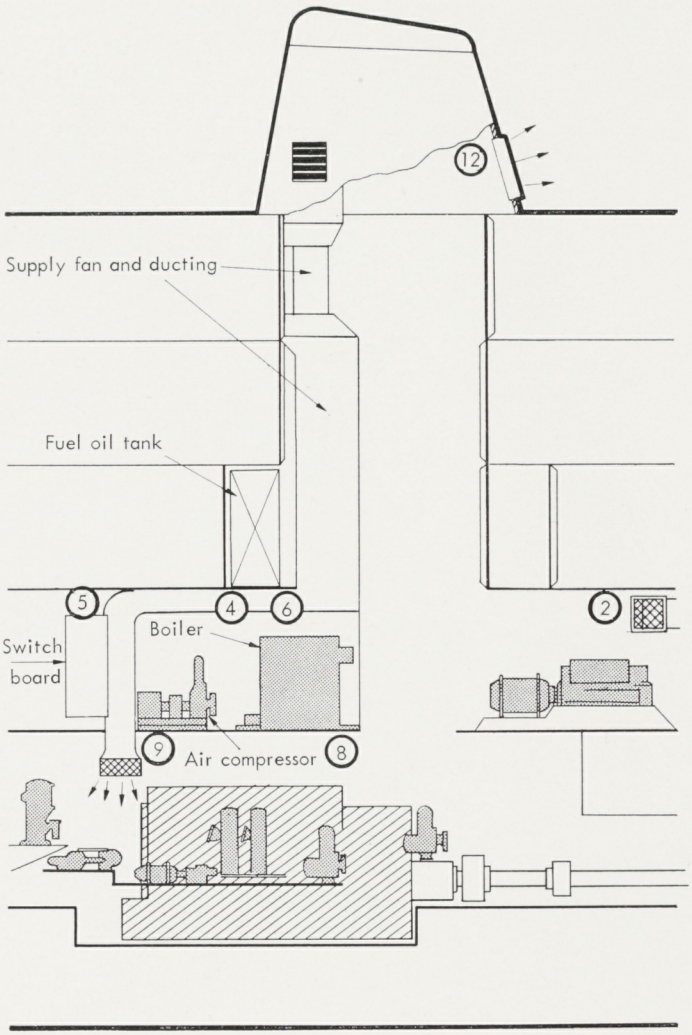



FIG. 37

Layout of detectors in machinery space.

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*Lloyd's Register Staff Association*

# THE SURVEY OF CREW ACCOMMODATION

J. R. G. Smith and J. W. Barron

Paper No. 4. Session 1970-71

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Hon. Sec. T. Swiatecki
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LLOYD'S REGISTER STAFF ASSOCIATION

PAPER No. 4, SESSION 1970–71

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# THE SURVEY OF CREW ACCOMMODATION

by J. R. G. Smith and J. W. Barron

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## CORRECTIONS AND ADDITIONS

Page 7 General Layout Table (2).

Persons per Room: Chief Radio Officer or only Radio Officer should be included under Officers having a single room to themselves.

Page 8 General Layout Table (3).

The reference in the top right hand box should read "SEE ALSO GENERAL LAYOUT TABLE (5)".

Page 11 In the right hand column in the line above the example the word "quality" should read quantity".

Page 13 In the fourth column of the table, the heading "Vol" should read "Vel". (Meaning velocity.)

# THE SURVEY OF CREW ACCOMMODATION

By J. R. G. SMITH and J. W. BARRON

## INTRODUCTION

When a Surveyor to Lloyd's Register of Shipping is called upon to carry out a survey of crew accommodation he is usually on strange ground, as such a survey is outside his normal everyday classification and statutory survey work. Nevertheless, when the Society is required to carry out a Crew Accommodation Survey this must obviously be done with the same professionalism which characterises the rest of the Society's work, and this paper is intended as an aid to that end.

The Society's collective experience on this subject is comparatively limited, and the Authors themselves are by no means experts. It is hoped, therefore, that all with experience in this field will contribute to the discussion.

## SYNOPSIS

The object of this paper is to guide the Surveyor through the obtusely worded Regulations.

The paper is presented entirely from the point of view of new construction, it being considered that for any survey on an existing ship the main content would still be applicable.

The main body of the paper is presented in two parts, namely "Survey Procedure" and "Survey".

"Survey Procedure" covers surveys required to be carried out by the Society at the request of an owner, and surveys carried out by individual Surveyors to the Society on behalf of the British Board of Trade.*

The major part of the paper is concerned with the actual survey, from the submission of plans to the final tests and inspections as illustrated in the Survey Chart. The requirements of the Regulations, where thought necessary, have been re-stated, it is hoped in simpler terms, and re-arranged for easier use. Some known British Board of Trade interpretations of certain requirements, not printed in the published Rules, are also included.

It is stressed that the paper is intended for use in conjunction with the published Regulations and not as a replacement for them.

## SURVEY PROCEDURE

### (a) Surveys carried out by the Society at the request of an Owner

When the Society is requested to carry out a survey of crew accommodation, the end object is to furnish the owner with a document stating that in the Society's opinion the crew accommodation is considered to be in accordance with the particular Regulations specified. These are normally either the British Crew Accommodation Regulations or the International Labour Organisation Regulations (*see* "Survey" page 1).

Requests for such a survey by the Society should be made at an early date and plans as indicated on the Survey Chart submitted to Headquarters in triplicate by the builders through the local Surveyors. Two copies of each plan will be returned to the Surveyors after examination, together with any comments or instructions which may be necessary. The Surveyors will also be sent a copy of the appropriate Regulations. The survey should then be carried out in accordance with these Regulations, instructions, approved plans, and with guidance from this paper. On completion the Surveyor should issue to the owner a Report 10 worded as in Figs. 1 or 2.

### (b) Surveys carried out by the Society's Surveyors on behalf of the British Board of Trade

With the growing number of British ships being built abroad, the Society is becoming increasingly involved in Statutory Surveys on behalf of the British Board of Trade. The procedure leading up to such surveys is as follows:—

1. The Board of Trade advise the Society's London Headquarters that a ship is to be built abroad and registered in the United Kingdom, stating Builder, Builder's Yard Number, and Builder's Address. The Board request the Society to nominate a Surveyor to carry out the necessary Statutory Surveys on their behalf. These consist of a Safety Equipment Survey, and Tonnage Admeasurement in addition to the Crew Accommodation Survey.
2. The Society's London Headquarters forward this request to the Senior Officer responsible for the Society's operations in the country concerned.
3. The Senior Officer then nominates a Surveyor, and this nomination, if acceptable to Headquarters, is passed on to the Board. The Surveyor nominated is usually the resident Surveyor at the particular builder's yard concerned.
4. The Board then officially appoints the nominated Surveyor to carry out the Statutory Surveys, and all subsequent correspondence is then between the Board and the Surveyor himself. The Surveyor submits to the Board for approval all plans requested by them, together with proposals for the various test procedures, etc. In order to minimise the cost of postage, which can be considerable, the Board does not return copies after approval. Any amendments, criticisms and further requirements are advised by letter. Instructions for Tonnage Admeasurement are also sent to the Surveyor.
5. On completion of the surveys the Surveyor submits direct to the Board final comprehensive reports on Crew Accommodation and Safety Equipment, together with a complete record of all test results.

## SURVEY

As stated on page 1 the two main sets of Crew Accommodation Regulations which will concern the Surveyor are the International Labour Organisation Crew Accommodation Regulations and the British Crew Accommodation Regulations 1953 and Amendments. The British Regulations are fundamentally based on the International Labour Organisation Regulations, but are much more detailed.

The International Labour Organisation Crew Accommodation Regulations are in fact rather vague and leave much "to the satisfaction of the Authorities". For the sake of consistency, therefore, the Society generally uses the British Regulations as guidance unless there are some specific

* The Board of Trade is now known as the Department of Trade and Industry.

# LLOYD'S REGISTER OF SHIPPING

Port _____

_____

**This is to Certify** that

_____

the undersigned Surveyor to this Society did at the request of

the
attend at on and
subsequently for the purpose of certifying compliance with the
Merchant Shipping (Crew Acccommodation) Regulations 1953 and
Amendments in respect of the single screw motor ship
Builders Yard No.

The arrangements have been examined and are considered to comply with the aforesaid Regulations with the exception of the following:-

Compliance with the British published Regulations as herein indicated is not to be taken to imply British Board of Trade Approval of these arrangements.

.....
Surveyor to Lloyd's Register
of Shipping.

This Certificate is issued upon the terms of the Rules and Regulations of the Society, which provide that:—

"While the Committees of the Society use their best endeavours to ensure that the functions of the Society are properly executed, it is to be understood that neither the Society nor any Member of any of its Committees is under any circumstances whatever to be held responsible for any inaccuracy in any report or certificate issued by the Society or its Surveyors, or in any entry in the Register Book or other publication of the Society, or for any error of judgment, default or negligence of any of its Committees or any Member thereof, or the Surveyors, or other Officers or Agents of the Society."

(Rpt. 10) 50m,2,63 (MADE AND PRINTED IN ENGLAND)

FIG. 1

# LLOYD'S REGISTER OF SHIPPING

Port _____

**This is to Certify** that

_____

the undersigned Surveyor to this Society did at the request of

the
attend at on and
subsequently for the purpose of certifying compliance with the International Labour Organisation Crew Accommodation Regulations in respect of the single screw motor ship
Builders Yard No.

The arrangements have been examined and are considered to comply with the aforesaid Regulations with the exception of the following:-

.....
Surveyor to Lloyd's Register
of Shipping.

This Certificate is issued upon the terms of the Rules and Regulations of the Society, which provide that:—

"While the Committees of the Society use their best endeavours to ensure that the functions of the Society are properly executed, it is to be understood that neither the Society nor any Member of any of its Committees is under any circumstances whatever to be held responsible for any inaccuracy in any report or certificate issued by the Society or its Surveyors, or in any entry in the Register Book or other publication of the Society, or for any error of judgment, default or negligence of any of its Committees or any Member thereof, or the Surveyors, or other Officers or Agents of the Society."

(Rpt. 10) 50m,2,63 (MADE AND PRINTED IN ENGLAND)

FIG. 2

National Regulations countermanding the same. This paper, therefore, deals only with the British Regulations.

Throughout the paper reference to the Regulations means the British Crew Accommodation Regulations 1953 and Amendments. Reference to the Handbook means the British publication "Crew Accommodation in Merchant Ships—Handbook for the Guidance of Shipowners". Reference to I.L.O. means International Labour Organisation.

References to the following types of ships have not been included:—

(i) Whalers.
(ii) Tugs.
(iii) Coal burning ships.
(iv) Ships making voyages of not more than three days duration.
(v) Ships less than 3,000 gross tons.
(vi) Passenger ships.

It is very unlikely that the Society would be required to carry out a Survey of Crew Accommodation on any ship in these categories.

When the Society is requested to carry out a survey in compliance with the British Regulations, the Regulations as amplified by this paper are to be applied in full, and any deficiencies stated on the final Report 10. When compliance with the I.L.O. Regulations is required the British Regulations as amplified by this paper are to be used as guidance, but some discretion exercised over the enforcement of detail requirements. If in any doubt Headquarters should be contacted without hesitation.

The lynch pin of the paper is the Survey Chart on the centre pages which illustrates a complete survey sequence from the submission of plans to the final tests and inspections. A comprehensive list of final tests and inspections is shown on page 5.

The Survey Chart is, of course, based on a Computer Flow Chart. In many cases where the building yard has its own computerised production programme, it is thought that this particular section of the yard's own Flow Chart could be utilised in this way. The Surveyor would then be able to control the survey and know exactly where he is at any time.

Alternatively, the Survey Chart could be extracted from the paper and a print taken of it for use as the necessary control. To enable this to be done the Chart has been arranged at the centre of the paper for easy withdrawal.

The term Survey Control should be kept clearly in mind and this cannot be emphasized too strongly. In these days of rapidly advancing ship and shipbuilding technology, ships are becoming bigger and more complex and are building in shorter and shorter periods of time. As the Surveyor's work load is therefore increased, Survey Control becomes a vital concept. An essential condition of such control is to know clearly what is required and to ensure that the builder also knows. A full discussion should be held with the builder before building commences. Using the Chart as a guide, the Surveyor should advise the builder at which specific point he will require an official survey. A list of final tests and inspections should also be presented to, and discussed with, the builder at this time. The builder can then fit the Surveyor's requirements smoothly into the building schedule to the obvious benefit of all concerned. The Surveyor's usual surveillance of work in progress between "official" surveys complete the total survey in the required controlled fashion.

The importance of the "running patrol" cannot be stressed too strongly to young Surveyors. It is by observing closely the work in actual progress that deficiencies are picked up and corrected at an early stage, thus saving the builder both time and expense.

It will be noted from the Survey Chart that the Survey of Crew Accommodation overlaps the Safety Construction Survey insofar as Fire Protection requirements in Crew Accommodation are concerned. These requirements are discussed on page 18.

Each plan listed on the Survey Chart is now taken separately and discussed, together with the relevant inspections and tests at the ship. Each plan should be submitted in triplicate at an early date.

## LIST OF TESTS AND INSPECTIONS

| ITEM | TEST OR INSPECTION DATE | REMARKS |
|---|---|---|
| Accommodation layout including galleys, hospitals and medical cabinet | | |
| Furniture and fittings in cabins, offices and mess rooms | | |
| Fittings in toilets and bathrooms | | |
| Fittings in laundry and drying rooms | | |
| Fittings in galley and pantries | | |
| Fittings in hospital and medical cabinet | | |
| Mosquito screens | | |
| Final overall inspection of complete accommodation | | |
| Natural ventilation | | |
| Mechanical ventilation | | |
| Heating | | |
| Air conditioning installation | | |
| Fresh water and sanitary water services—tightness, etc., before erection of linings and ceilings | | |
| Fresh water services—working test including standby pump | | |
| Testing hot water for 150° F at all draw-off points | | |
| Testing showers anti-scalding mixing valves for 103° F maximum | | |
| Sanitary water services—working test including standby pump | | |
| Cooled drinking water supply | | |
| Scuppers and sanitary discharges—tightness, etc., before erection of linings and ceilings | | |
| Scuppers and sanitary discharges working test, inspection of ship's side valves, etc. | | |
| Locking wash down taps and notices in galley and pantries | | |
| Electric lighting installation including emergency system<br>Natural lighting | | |
| Deck coverings and insulation | | |
| Awnings | | |
| Dry storerooms | | |
| Refrigerated storerooms and hospital emergency alarm | | |
| *"SAFCON" Survey items*<br>Source of emergency electrical power as regards lighting | | |
| Fitting of fire bulkheads in crew accommodation | | |
| Penetrations of fire bulkheads by pipes, vent trunks and electric cables. (To be examined before the erection of ceilings, etc.) | | |

## 1. ACCOMMODATION LAYOUT INCLUDING GALLEYS, HOSPITAL AND MEDICAL CABINET

It is considered that the most important aspect of the Survey of Crew Accommodation is the layout. If crew spaces are actually located incorrectly then there is not much point in worrying about detail. A good deal of thought has, therefore, been given to general layout and the requirements reduced to note form and presented in tables in order to reduce verbiage. These tables largely cover the requirements of Regulations 4, 5, 6 and 9, together with the appropriate paragraphs in the Handbook. Regulations 16, 19, and 21 to 32 are also covered insofar as general layout is concerned. For further details, together with the requirements for furniture and fittings, etc., the actual Regulation and appropriate paragraph in the Handbook must be consulted.

The tables covering the general layout are made up as follows:—


Table (1) General Notes page 6
Table (2) Cabins, Mess Rooms, Offices, etc. page 7
Table (3) Washing Accommodation and Water Closets page 8
Table (4) Laundry, Drying Rooms, etc. page 8
Table (5) Internal Bulkheads page 9


### GENERAL LAYOUT TABLE (1) GENERAL NOTES

All crew accommodation other than storerooms to be situated above the Summer Load Water Line at either amidships or aft. Crew accommodation to be accessible at all times from the open deck. Access to sleeping rooms, mess rooms, recreation rooms and studies to be from a passageway provided with a hinged door at any entrance from the open deck. Bulkheads exposed to the weather to be of steel or other suitable material, to be watertight and gastight. All openings therein to be provided with weathertight closing appliances. (Note.—Not necessarily weathertight as required by the 1966 Load Line Rules, i.e. unless a door is in such a position that compliance with Reg. 12 of the L.L.C. is required, then hardwood doors would be acceptable from the crew accommodation point of view, provided they were of adequate strength and construction and substantially weathertight bearing in mind the position of the door. Such doors would be expected to be a minimum of 2 inches thick).

The crew accommodation and means of access to and egress from to be arranged, constructed and situated in such a position as to ensure:—

1. Protection of crew against (a) injury or discomfort, (b) weather and the sea, (c) moisture due to condensation. In particular, hawse pipes are not to be situated in crew accommodation and chain pipes and cargo vent trunks are to be of steel gastight construction where passing through crew accommodation. Also in crew space, steam pipes, hot and cold water pipes and calorifiers to be lagged where necessary. Also batteries are not to be placed in any sleeping room and precautions to be taken to ensure that battery fumes do not discharge into any part of the crew accommodation. *See also* Staff Association Paper on the 1966 Load Line Convention, by Messrs. Simpson, Bates and Beckwith, Regulation 19, as regards British Ships (page 25), also M 1306 of the Society's Rules.
2. Insulation of the crew accommodation from heat and cold.
3. Exclusion against effluvia and noise originating in other spaces in the ship.

Also:—

4. See Survey Chart for note regarding steam supply and exhaust pipes for steering gear, etc.
5. Natural lighting to be provided in accordance with Regulation 11. *See also* page 17.
6. *See also* Regulation 33 and paragraph 41 on the Handbook for "Protection against Mosquitoes", also page 10 of this paper.
7. The Safety Construction Rules and Chapter D of the Society's Rules require that in and from all crew spaces in which crew are normally employed (other than machinery spaces, which are not within the scope of this paper), stairways and ladders are to be arranged so as to provide a ready means of escape to the lifeboat embarkation deck.

# GENERAL LAYOUT TABLE (2)

(Cabins, Mess Rooms, Offices, etc.)

<table>
<tr><td></td><td colspan="6">CLASSES OF PERSONS TO BE SEPARATE FROM OTHER CLASSES</td></tr>
<tr><td></td><td>Officers</td><td>Apprentices</td><td>Petty Officers</td><td>Deck Ratings (not P.O.'s)</td><td>E.R. Ratings (not P.O.'s)</td><td>Catering Staff (not P.O.'s)</td></tr>
<tr><td>PERSONS PER ROOM</td><td>One for:— Chief Officer, Chief Engineer, other officers where possible and in no case more than 2</td><td>Where practicable not more than 3 and in no case more than 4</td><td>One for:— Bosun, Chief Steward, Chief Cook (or only Steward or Cook) other P.O.'s where possible and in no case more than 2</td><td colspan="3">Where practicable not more than 3 and in no case more than 4</td></tr>
<tr><td colspan="7">Minimum Floor Area:—<br>British crew (or equivalent) — 30 square feet per person<br>Crew as in Reg. 38(2) (i.e. Non-British) — 20 square feet per person<br>Space occupied by berths, lockers, seats or chests of drawers to be taken into account. Small or irregular shapes which cannot accommodate furniture and do not allow free movement not to be taken into account, e.g. space occupied by frame chocks or between frame brackets if not covered by furniture and not available for free movement.</td></tr>
<tr><td colspan="7">Minimum height: 7′ 6″ heel of beam to heel of beam. 6′ 3″ clear in spaces available for free movement.</td></tr>
<tr><td>MESSING ARRANGEMENTS<br>Recreation Rooms, Offices and Studies</td><td colspan="2">1 office required for Chief Officer or Deck Officers and 1 office required for Chief Engineer or Engineer Officers. Single mess for all officers. Deck and Engineer Officers may have separate mess rooms if their cabins are widely separated. Separate smoking room to be provided.</td><td>Separate mess for apprentices or may use officers mess. If more than 2 apprentices to one sleeping room, separate study required.</td><td colspan="3">Recreation accommodation required for ratings, either in the mess room or elsewhere. To be appropriately situated. Space also required on open deck for recreation purposes. (Separate spaces if different national habits.)<br>Deck & Eng. P.O.'s may have separate mess rooms, or may share. | Deck & Eng. ratings (not P.O.'s) may have separate mess rooms, or may share. | Separate mess room for catering staff (not P.O.'s).<br>P.O.'s and other ratings of the same department may share a mess room.<br>Single mess rooms for P.O.'s and rating of deck and eng. departments and catering staff would be specially considered if required. A bookcase is to be available to all members of the crew.</td></tr>
</table>

## GENERAL LAYOUT TABLE (3)

### (Washing Accommodation and Water Closets)

| | | |
|---|---|---|
| WASHING ACCOMMODATION & WATER CLOSETS.<br>Separate WASHING ACCOMMODATION and separate WATER CLOSETS for:—<br>(a) Officers & Apprentices<br>(b) Petty Officers<br>(c) Other Ratings | LOCATION: Close to sleeping rooms. Engineers wash room may be adjacent to engine room. W.C. to be situated close to any Radio Officer whose sleeping room is remote from other sleeping rooms. If cooks' washing accommodation is far from galley, a wash basin to be provided in or near the galley. | ACCESS: From passageways where possible. *Not* from mess rooms. *Not* from sleeping room except from not more than 2 sleeping rooms accommodating not more than 4 persons if the wash rooms and/or W.C. is solely for the persons in those sleeping rooms.<br><br>SEE ALSO GENERAL LAYOUT TABLE. |
| 1—Bath or shower for every 8 persons of each class<br>1—Washbasin for every 6 persons of each class<br>1—Water Closet for every 8 persons of each class<br><br>No account to be taken of private baths, showers or W.C.'s, or of the persons to whom they are appropriated. Hospital washing accommodation and W.C. to be counted separately. | When dividing number of persons by 8 or 6; the number of baths, showers, or W.C.'s is to be the nearest whole number to the quotient so obtained (0·5 is rounded up). | Wash basins and water closets to be of vitreous china or other material having a smooth and impervious surface not likely to crack, flake, or become corroded. The U.K. Rules state that W.C.'s must be white and have a seat of polished hardwood or other suitable material, with an opening of 4 inches at the front. A handrail or grip and a device for holding toilet paper is required at each W.C. Every bath or shower space to be provided with a grating or mat. |
| Minimum internal length of bath=4′ 5″ unless combined with a shower.<br>Minimum length of each side of shower space to be 2′ 6″.<br>Minimum area of shower space to be 6·25 square feet.<br>Minimum wash basin capacity=1·5 gallons, measured to a level of at least 1·5 inches below the rim of the bowl. | | |

## GENERAL LAYOUT TABLE (4)

| | |
|---|---|
| LAUNDRY | Clothes washing troughs for crew to be adequate in size and number. To be made of or coated with hygenic and durable material, with a smooth impervious surface, not likely to crack, flake or corrode. *Laundry room to be provided for such troughs.* (Unless situated in crew's washing accommodation, but special approval required for this.) |
| DRYING ROOMS | To be separate from sleeping rooms, mess rooms, recreation rooms, offices, store rooms, galleys, pantries and hospitals. To be fitted with racks or rods with sufficient space. For heating and ventilating (*see* page 10). |
| OILSKIN AND WORKING CLOTHES LOCKERS | Separate compartments required for officers and ratings. To be situated outside sleeping rooms and easily accessible therefrom. |
| GALLEY | To be near the mess rooms. To be protected from sources of excessive dirt. To have no direct opening to sleeping rooms. Natural lighting to be provided from all exposed sides and above (*see also* page 17). |
| DRY PROVISION STORE ROOMS | At least one to be provided. To be enclosed by steel bulkheads. Access to be obtained from a passageway, galley, pantry or another store room, or from a protected position on the open deck. Not to be situated over a boiler room or source of heat, not adjacent to a galley or machinery casing (but *see* Insulation, page 16). |
| COLD STORES AND REFRIG. MACHINERY | Access to stores to be from a passageway, galley or pantry, or from another store room. The refrigerating machinery space to be gastight where abutting crew accommodation. Access to refrigerating machinery space to be from open deck or, if access is from a passageway or other crew space, the door is to be spring loaded, jointed and gastight (*see also* page 17). |
| HOSPITAL (Medical cabinet to be provided adjacent to the Hospital) | To be used solely as a hospital. To be in quiet, comfortable situation and readily accessible from the cabin of the Master, or person appointed to take charge of patients. Situation also to take into account the treatment of patients in all weathers. Entrance to be a minimum of 30″ in width, and arrangement should facilitate the carriage of a stretcher into the hospital and of it being placed alongside at least one single tier bed. Either (a) natural light to be provided on at least two sides through 12″ diameter sidescuttles, or (b) on at least one side in association with opening type skylight as large as practicable, or (c) mechanical ventilation provided. A W.C. to be provided with access direct from the hospital. Wash basin to be provided and in ships over 5,000 gross tons a bath having at least 4′ 5″ internal length. W.C. will, therefore, normally be installed in a bathroom and the door is to be gastight and self-closing unless mechanical ventilation provided. B.O.T. requirement additional to published Rules is that the bathroom door should open into the hospital. |

# GENERAL LAYOUT TABLE (5)

## INTERNAL BULKHEADS

(Safety Construction Rules and Chapter F of the Society's Rules to be complied with)

Refer to diagram below for type of bulkhead, i.e. bulkhead separating sanitary accommodation from oil fuel bunkers should be type A.

| | | |
|---|---|---|
| | 1. Sanitary accommodation<br>2. Laundry or drying room<br>3. Galley or cold store room<br>BHD "B" | (a) Oil fuel bunker<br>(b) Cargo or machinery space<br>(c) Lamp room or paint room<br>(d) Store room not forming part of crew accommodation other than a dry provision store.<br>(e) Chain locker or cofferdam<br>BHD "A" |
| DRY PROVISIONS ROOM | BHD "C" Crew accommodation | Crew accommodation other than recreation deck space |

BHD "A"

Inside panelling in the crew accommodation to be of plywood or other suitable material with a surface which can be easily kept clean. Any material or type of construction likely to harbour vermin, such as tongued and grooved boarding is not permissible either for panelling or bulkheads.

BULKHEAD A. To be gastight. Also to be watertight where necessary to protect the crew accommodation. No direct openings permitted, except to passageways.

BULKHEAD B. To be gastight. Also to be watertight to such a height as is necessary to prevent the passage of water into the adjoining space. In particular any bulkhead separating sanitary accommodation from any other part of the crew accommodation is to be at least 9″ above the floor of the sanitary accommodation (except in a doorway). No direct openings permitted. This does not apply to bulkheads separating:—

(a) Sanitary accommodation from other sanitary accommodation.
(b) Laundry or drying room from other laundry or drying room.
(c) A galley from another galley or a pantry.
(d) A cold store from another cold store.
(e) Sanitary accommodation appropriated for the sole use of one person from a sleeping room from which it may be directly entered.

BULKHEAD C. To be gastight.

No direct opening is permissible between the crew accommodation (other than recreation deck spaces) and engine or deck storerooms.

Crew accommodation adjacent to an oil tank (other than the crown of the oil tank) to be separated by a gastight steel cofferdam. Special approval to be sought for any deviation. Crew accommodation situated on the crown of an oil tank to be separated by an oiltight deck, and no manholes or other openings are permitted inside the crew accommodation.

Access to and from all crew accommodation to be so situated that in the event of fire in any lamp or paint room in the ship, such access will not be impeded.

All doors to engine casing, S.G. room, $CO_2$ room or refrigerating machinery room from crew accommodation passageways are to be self closing and gastight, unless a suitable air lock is provided.

It should also be noted that Rules 9(1) (6) and 12(2) of the British Merchant Shipping (Radio) Rules 1965 require that the Radio Room and the Battery Room be placed as high in the ship as practicable. This ruling is also applicable under Chapter 4 Part C of 1960 S.O.L.A.S. Regulations. The sleeping accommodation of at least one radio officer is to be situated as near as possible to the radio room, and detailed requirements are set out in paragraph 27(2) of the Handbook.

Regarding the provision of mess rooms the British Board of Trade have accepted in the past two combined mess rooms, one for Petty Officers of all departments and the other for Ratings of all departments, there being no separate mess room for Ratings of the catering department. The Board, however, required written assurance from the owners that a messman or similar rating would be responsible for keeping the ratings mess room clean.

The fitting out of sleeping rooms, mess rooms, etc., are adequately covered in the Regulations. References are as follows:—

| | |
|---|---|
| BEDS | Regulation 17 and paragraph 27 of the Handbook. |
| FURNITURE AND FITTINGS IN SLEEPING ROOMS | Regulation 18 and paragraph 27 of the Handbook. |
| FURNITURE AND FITTINGS IN MESS ROOMS | Regulation 19 and paragraph 28 of the Handbook. |
| WASHING ACCOMMODATION | Regulation 23 and paragraph 30 of the Handbook. |

Compliance with these Regulations and with the general layout tables 1 to 5 should be shown on the accommodation layout plans submitted for approval. Such plans should also show compliance with the requirements for galleys, hospitals, etc. The requirements for galleys, hospital and medical cabinet are covered in the Regulations and the Handbook as follows:—

| | |
|---|---|
| GALLEYS | Regulation 28 and paragraph 34 of the Handbook. Further references are made in this paper under Ventilation page 10), Supply of Hot and Cold Fresh Water (page 12), Supply of Sanitary Water to Water Closets, etc. (page 12), and Scuppers and Sanitary Discharges (page 14). |
| HOSPITALS | Regulation 31 and paragraph 39 of the Handbook. Further references are made in this paper under Ventilation (page 10) and Scuppers and Sanitary Discharges (page 14). |
| MEDICAL CABINET | Regulation 32 and paragraph 40 of the Handbook. |

Protection is also required throughout the accommodation against mosquitoes and this is covered by Regulation 33 and amplified by paragraph 41 of the Handbook. Exemption from the provision of mosquito protection may be granted by the Board of Trade, provided that all opening side scuttles and windows are fitted with special locking arrangements, the opening of which must be under the control of the Master or duly appointed Senior Officer who must be instructed that these openings must be kept closed in the ports detailed in Regulation 33(3). A further condition is that doors leading to the open deck must be of a self-closing type.

## 2. VENTILATION AND AIR CONDITIONING (ALSO HEATING)

(See also SAFCON Requirements, page 18)

The basic requirements for ventilation are clearly laid down in Regulation 12, in association with First Schedule at the back of the Rule Book appertaining to a trunked mechanical ventilation system.

The Schedule includes a table which splits the various spaces into separate categories and lists the fresh air changes per hour required, and also the volume of fresh air, in cubic feet per minute, for each person likely to use the room at any one time. A further table is included for galleys, sanitary accommodation, drying rooms, pantries, hospital wards and dry provision rooms, which lists the required air changes per hour under supply and exhaust. The paragraphs preceding the tables should also be read carefully.

Further references are made to ventilation requirements throughout the Rules as follows:—

REGULATION 26(2). Drying rooms to be provided with exhaust ventilation, independent of the ventilation of all other spaces in the ship unless it is provided by a trunked mechanical ventilation system.

REGULATION 26(3). Oilskin lockers to be adequately ventilated.

REGULCTIONS 27(5). Doors between a water closet and a passageway ta be close fitting and without apertures unless the exhaust ventilation arrangements from the water closet render this unnecessary.

REGULATION 27(7). Every water closet to be completely enclosed by bulkheads, and to be provided with exhaust ventilation directly to the open air or to another water closet which is provided with ventilation directly to the open air. Provided that a water closet may be separated by a partition consisting of steel or other opaque and rigid material open at the top and bottom from:—

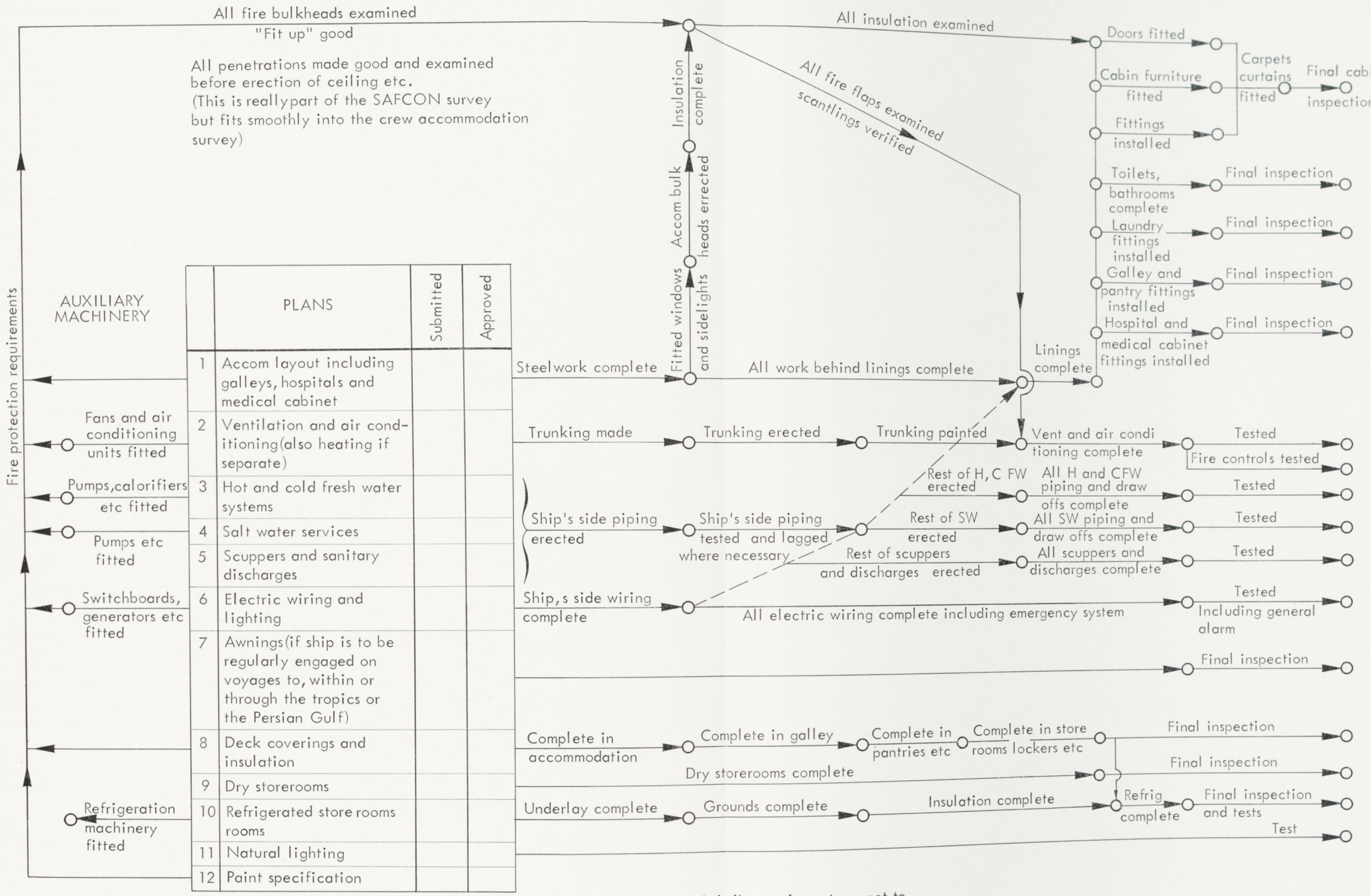
(a) Another water closet,
(b) a urinal, or
(c) washing accommodation if the water closet is served by a trunked mechanical ventilation system which effectively removes the odours therefrom.

REGULATION 28(9). Every galley to be provided with exhaust fans which will draw off fumes from the cooking appliances therein and discharge the fumes into the open air, except when the galley is so situated that the fumes can discharge only into the open air.

REGULATION 29(4). Every dry provision room shall be so situated, constructed and ventilated as to avoid deterioration of the stores through heat, draught, condensation or infestation by insects or vermin.

REGULATION 30(3). The refrig. machinery room is to be gastight where it abuts upon other parts of the crew accommodation and is to be adequately ventilated by at least two ventilators to the open air, one of which is to be fitted with an exhaust fan and is to have its inlet near the bottom of the room or space. The motor of the fan and the electrical connections thereto to be enclosed in a spark-proof case.

REGULATION 31(7). In addition to any mechanical ventilation, every permanent hospital is to be provided with adequate natural supply and exhaust ventilation to the open air by means of ventilators, independent of the ventilators pro-




Note : Steam supply and exhaust pipes for steering gear, winches and similar equipment are not to pass through crew accommodation. If, however alternative arrangements are considered unreasonable or impracticable, such pipes could be permitted to pass through passageways, subject to being properly encased and complying with Chapter E section 6 of the Society's Rules. Full details of proposed arrangement then to be submitted.

**Crew accommodation survey chart**

vided for any other space on the ship. Special approval would be required for non-compliance.

REGULATION 31(8). Every permanent hospital to be provided with an electric fan, unless it is served by a trunked mechanical ventilation system.

REGULATION 31(16)(d) and (e). The room in which the hospital w.c. is installed is to be provided with a gas-tight self-closing door unless it is served by a mechanical system of exhaust ventilation. The room is to be ventilated in the manner specified for water closets in Regulation 27(7).

REGULATIONS 33. "Protection against Mosquitoes" (*see also* page 10 of this paper).

The Blue Handbook, "Crew Accommodation in Merchant Ships", contains more detailed requirements, the relevant paragraphs being as follows:—

PARAGRAPH 22. This covers ventilation and is supplementary to Regulation 12.

PARAGRAPH 23. This covers electric fans and is supplementary to Regulations 12(4) and 31(8).

PARAGRAPH 24. This covers mechanical ventilation and is supplementary to Regulation 12.

PARAGRAPH 41. "Protection against Mosquitoes" (*see also* page 10 of this paper).

**General Notes on Ventilation**

It is common practice to ventilate cabins by mechanical supply and natural exhaust, the natural exhaust occurring through jalousies in cabin doors to passageways. In general terms a free area of 30–40 square inches is usually provided for these jalousies. Generally, the jalousies size should be about twice the free area required, dependent upon the size and angle of the frets. For this system to work it is obvious that the air pressure in the cabin must be greater than the air pressure in the passageway.

Toilets usually have mechanical supply and exhaust, especially where an air conditioning system is installed. The beneficial effects of fresh air can thus be concentrated on the personnel through punkah louvres, and the supply may be heated if required. The volume of air supplied is usually not much in excess of half the amount extracted. This is to keep the pressure in the toilet less than that in the adjacent spaces.

The following also applies to the ventilation of toilets:—

(a) Natural supply and natural exhaust.

(b) Natural supply drawn from passageways and mechanical exhaust.

(c) Mechanical supply and natural exhaust.

Each system should be considered on its merits, reference being made to Regulation 27(7) and Regulation 31(16) (d) and (e).

Each mechanical supply branch to a toilet space should be fitted with a non-return valve to prevent back flow by effluvium in the event of failure of the supply fan. (Handbook paragraph 24(1)(d)). Non-return valves in exhaust trunking from toilets are only necessary when toilets are exhausted with other spaces. It is preferable, however, to have toilet spaces exhausted via one common trunk system with branches to other compartments kept to a minimum. It is important that the discharges from fans serving w.c.'s should be carefully sited away from all supply inlets.

Compliance with the requirements in respect of fresh air changes per hour is the responsibility of the manufacturers of the ventilation system. This point should be emphasised to the manufacturers and also to the owners. Ventilation is a very wide subject and is further complicated by the increasing use of air conditioning systems. There are numerous types of systems, such as the central air conditioning system, twin-duct air conditioning system, re-heat air conditioning system and many more. Much must be left, therefore, to the ventilation engineers concerned in the matter of compliance with the requirements of the First Schedule. If an air conditioning system is to be installed, then a full description or specification of the system including air changes, together with a diagrammatic sketch of the basic principles involved, should be submitted with the normal arrangement plans. Plans of natural ventilation should also be submitted.

Compliance with the requirements as regards fresh air changes per hour is to be verified by a test and the test results forwarded to London Headquarters. The test and the method of measuring the air changes per hour is again the responsibility of the ventilation or air conditioning engineer, but the Surveyor should witness the tests and verify the figures produced. A copy of the results should be forwarded to London Headquarters with a description of the method used for measuring the air changes. For example *see* page 13.

If an air conditioning system is installed care should be taken to measure the actual *fresh* air changes per hour as opposed to re-circulated air. The owners and air conditioning engineers should be advised that figures somewhat less than those specified in the First Schedule would be accepted if the air was conditioned, provided the owners give a written assurance that the air conditioning system will always be available when the crew are on board. If such written assurance cannot be given, the system should be designed so that when operating as a mechanical ventilation system only, the exhaust ventilation, mechanical and natural, should be sufficient to allow *full* compliance with the First Schedule.

Likewise, awnings as required by Regulation 9(2)(k) may be omitted provided the omission is taken into account in the design condition of the air conditioning system, and provided the owners give written assurance that the system will always be available when the crew are on board.

Regarding the actual measurement of air changes, perhaps the most common method is by use of an anemometer. The anemometer consists essentially of concentric vanes which are caused to rotate by the moving air, and a gauge which registers the number of feet of air passing the vanes. By using the anemometer in conjunction with a stopwatch it is easy to calculate the velocity of the air in feet per minute. The quantity (in cubic feet per minute) discharged from the punkah louvre or other opening is obtained by multiplying this velocity by the area (in square feet) of the opening. Where the opening or louvre is greater in area than the instrument, the latter should be moved over the total area so that the reading is the average quality for the whole opening.

EXAMPLE: If over a period of three minutes the anemometer indicates that 780 feet of air have been delivered by a 6″×6″ opening:—

Velocity $=780\div3=260$ feet per minute

Area $=0{\cdot}25$ square feet

$\therefore$ Volume $=260\times0{\cdot}25$

$=65$ cubic feet per minute

The above notes on measurement of air changes are given for Surveyors' guidance only, and it is again emphasised that

it is the responsibility of the ventilation or air conditioning engineers to measure such air changes to the satisfaction of the Surveyor.

**Heating**

The requirements are clearly laid down in Regulation 10, and substantiated by paragraph 20 of the Handbook. For the normal category of ships being covered by this paper the heating should be such as to maintain a temperature of 67° F when the ambient temperature is 30° F. This is to be so maintained with the mechanical ventilation system working so as to furnish at least 15 cubic feet of fresh air per minute per person accommodated in each space. The temperature within a water closet, however, need be maintained at no more than 10° F above the ambient, and if this temperature is capable of being maintained by heat derived from an adjoining compartment, a heating system need not be provided in the toilet.

A further reference to heating is made in Regulation 26(2) which requires that the heating of drying rooms be controlled independently of the heating of any other space in the ship.

**General Notes on Heating**

In the majority of cases where the Society is required to carry out Crew Accommodation Surveys on new construction, the heating will be provided via an air conditioning system. The following formula for obtaining the required temperature from such a system is acceptable to the Board of Trade:—

$$(0{\cdot}8 \times \text{ambient}) + 43$$

That is to say, if the outside temperature is 38·75° F, then the temperature in the accommodation should be ·8 (38·75)+ 43=74° F.

**Heating Test**

Thermometers should normally be placed in the cabin furthest from the fan, assuming that if the required temperature can be reached in such cabins the system will be satisfactory for the whole of the accommodation. Spot checks should be made, however, on selected cabins throughout the system, including those nearest to the fan, to ensure that the system is balanced, and that excessive temperatures are not reached.

Care should be taken to ensure that the heating test is not carried out when the ambient temperature is such that damage to fittings (warped doors, etc.) may be caused through attaining the resultant required temperature inside the accommodation. All too often, in tropical and subtropical countries, the Surveyor is forced to carry out the heating test in the small hours, when the ambient temperature is reasonable. The test should be run over a time period of about four to six hours to ensure a balance and an ability to sustain the temperature. Such systems usually attain the required temperature within the first hour, but it should be noted that the heating system should be capable of producing the required temperature (in relation to the ambient) within 24 hours.

A copy of the results should be forwarded to London Headquarters, with ambient and required temperatures stated as in the example on page 13.

## 3. HOT AND COLD FRESH WATER SYSTEMS

(See also SAFCON Requirements, page 18)

(i) **Supply of Drinking Water**

This is covered by Regulation 25, amplified in paragraph 32 of the Handbook, under the heading of "Water Supply Drinking and Cooking". The fitting of an automatic chlorination system is required by the British Board of Trade in cases where fresh water generators are fitted to provide potable water at an operating temperature of less than 212° F. The fitting of such a system does not alter the requirements for the positioning of fresh water tanks. The correct positioning of drinking and cooking fresh water tanks is vital and should be verified as being in accordance with the requirements at an early stage.

The Surveyor should satisfy himself that the cold drinking water system is protected from sources of heat. The piping should be tested to ensure tightness, preferably at twice the the working pressure, to take account of surges in the system. The working efficiency of the system should also be tested and, where an enclosed pressure system is employed, the automatic controls and the relief valve should be satisfactorily demonstrated. The system should also be tested using the standby pump required by paragraph 32(9) of the Handbook. Particular attention should also be paid to the draw-off taps required in galleys, bakeries, butcher shops, etc., and over all hot water boilers in mess rooms and pantries, including hospital pantries. These draw-off taps are to be suitably labelled.

(ii) **Supply of Hot and Cold Fresh Water to Washing Accommodation**

This is covered by Regulation 24 and amplified by paragraph 31 of the Handbook. Again, the positioning of fresh water tanks should be checked at an early stage. Hot and cold fresh water is to be laid on to a sink in the galley for washing-up purposes (Regulation 28(15)). The piping should be tested to ensure tightness, preferably at twice the working pressure, to take account of surges in the system.

The working efficiency of the system should also be tested and, where an enclosed system is employed, the automatic controls and the relief valve should be satisfactorily demonstrated. The system should also be tested, using the standby pump required by paragraph 31(3) of the Handbook.

The Surveyor should satisfy himself that the minimum required temperature of 150° F can be steadily maintained at all draw-off taps, and that every shower bath is provided with an anti-scalding mixing valve, adjusted so that the temperature can be varied from ambient to between 95° F and 105° F. Warning notices to be posted in all showers reading as follows: "Test cold water before using shower".

All draw-off taps to be suitably labelled and to be spring-loaded.

The Surveyor should also make use of the "Guidance Notes on Metal Pipes for Water Services" in Chapter R of the Society's Rules.

## 4. SALT WATER SERVICES

(See also SAFCON Requirements, page 18)

**Supply of Sanitary Water to Water Closets, etc.**

This is covered by Regulation 27(9)(b) and amplified by paragraph 33 of the Handbook. Attention should also be paid to Regulation 27(10) when provision is to be made for an Asian crew.

## RESULTS OF TYPICAL MECHANICAL VENTILATION AND HEATING TESTS

Ambient Temperature = 38·75°
Required Temperature in Accommodation = ·8 (38·75) + 43
= 31 + 43
= 74° F

| Space | Vol. Cu. ft. | Louvres No. Size (Reference see Plan) | Vol. f.p.m. | Output c.f.m. | Air Changes | | Temp. (° F) | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Required | Obtained | Required | Obtained |
| NAV. BRIDGE DECK | | | | | | | | |
| Chart Room/ Wheelhouse | 4880 | 3 No. 8 | 950 | 990 | 12 | 12·2 | 74 | 78 |
| BOAT DECK | | | | | | | | |
| Radio Room | 1040 | 2 D | 1850 | 180 | 10 | 10·4 | 74 | 74 |
| Owner's Toilet | 405 | 1 5NR | 2000 | 68 | 10 | 10·1 | | |
| Owner's Room | 1440 | 3 D | 1800 | 265 | 10 | 11·0 | | |
| Captain's Day Room | 1750 | 4 D | 1400 | 295 | 10 | 10·1 | 74 | 76 |
| Captain's Bedroom | 1040 | 2 D | 1850 | 180 | 10 | 10·4 | 74 | 77 |
| Captain's Toilet | 475 | 2 4NR | 1900 | 80 | 10 | 10·1 | | |
| Passage | 810 | 1 C | 1700 | 57 | 4 | 4·2 | | |
| Toilet | 200 | 1 3NR | 3000 | 36 | 10 | 10·7 | | |
| BRIDGE DECK | | | | | | | | |
| Steward | 650 | 2 C | 2100 | 143 | 10 | 13·2 | 74 | 88 |
| 3rd Officer | 950 | 2 D | 1650 | 160 | 10 | 10·1 | | |

NOTE.—The air changes per hour were measured with an anemometer. Re-size reference of punkah louvre (*see* separate plans enclosed).

As in the drinking water and hot and cold fresh water supply systems, the sanitary water supply should be satisfactorily tested and demonstrated. W.C.'s should be flushed individually to ensure that they are working.

Regarding standby pumping arrangements, one communal standby pump is permissible for the fresh water and sanitary water pumps provided a suitable arrangement of valves is fitted. A notice should be displayed for such a communal standby pump as follows: "The standby pump should be thoroughly flushed with fresh water before being connected to the fresh water system". There is, however, to be no connection between the separate drinking water service and any other system, and there should be no connection to the ballast line.

There is no objection to the provision of salt water for any baths or showers which are installed in excess of those required by the Regulations.

A draw-off tap is to be provided in the galley for washing the floor. If this tap is on the salt water system (and this is usually the case) there should be provided a suitable stop cock with locking arrangements to ensure that use is not made of the salt water system when in harbour or dock, or in any other place where the water may be foul. A notice should be fitted reading as follows: "Salt water only to be used when vessel is in the open sea". This also applies to any salt water draw-off tap for washing down purposes, in say, a pantry, dry provision room, wash place, etc.

Salt water taps are not to be fitted over a sink in any galley or other place in which food may be prepared for the crew.

The Surveyor should also make use of the "Guidance Notes on Metal Pipes for Water Service" in Chapter R of the Society's Rules.

## 5. SCUPPERS AND SANITARY DISCHARGES

(See also SAFCON Requirements, page 18)

Drainage is covered by Regulation 13 and amplified by paragraph 25 of the Handbook. Further references to scuppers and sanitary discharges are made throughout the Rules and the Handbook and the main requirements can be summarised as follows:—

(i) Scuppers must be fitted in sanitary accommodation. The scuppers are to be at least 2 inches in diameter and must not serve any other space. They are to be situated wherever water is likely to collect on the floor of the spaces. (Reg. 13(3)).

(ii) Each shower space to have individual drainage. (Reg. 23(8).) It should be noted that this Regulation requires each shower space to be provided with a kerb. It is the usual practice of one well known continental shipowner to make the level of the deck covering in the shower space 2 inches lower than the remainder of the washroom and toilet space. Instead of the usual washroom and toilet space scupper and shower drains, therefore, a shower drain only is fitted, this also serving as the washroom and toilet space scupper. A year or two ago the owner decided to have a ship built under the British Flag and the above arrangement fell foul of the British Board of Trade. The problem was eventually resolved as follows:—

(a) PRIVATE TOILETS. Drainage by means of the shower stall scuppers was accepted.

(b) CHANGING ROOMS. Where these spaces were fitted, with showers only, drainage via the shower scuppers was accepted.

(c) COMMUNAL WASH PLACES. As these compartments contained wash basins and water closets, the shower spaces were required to have a kerb fitted and separate scuppers provided for each individual shower space, and for the surrounding wash place. Generally, the British Board of Trade insist on each shower space being provided with a kerb and separate drainage in all cases, and the above was an exceptional case.

(iii) Waste pipes should be adequately ventilated (hygiene) and fitted in a manner which will minimise the risk of obstruction and facilitate cleaning. (Reg. 23(8.) For further guidance *see* Handbook, paragraph 25.

(iv) HOSPITAL (Reg. 31(15))

(a) No scuppers to be fitted in the hospital ward.

(b) 2-inch scupper required in hospital bathroom. This scupper may be linked with other sanitary discharges provided satisfactory traps are provided (*see* (ix).)

(c) Wash basin and bath and shower wastes to be separate from all other discharges if practicable. The British Board of Trade would require strong reasons to allow otherwise.

(v) GALLEY

(a) The floor to be provided with gutters and with scuppers which should be led overboard or to an enclosed tank served by two mechanically operated suction pumps. The position and number of the gutters and scuppers is to be such as to ensure sufficient drainage of the floor. (Reg. 28(10).)

(b) Galley scuppers and sink wastes should be independent where convenient. (Handbook, paragraph 25(10).)

(vi) $2\frac{1}{2}$-inch diameter scuppers required in each cold room (*see* Handbook, paragraph 37(3) (vii) for further guidance.) No piping should be led through cold rooms.

(vii) No pipes other than fresh water pipes are to pass through fresh water tanks. (Handbook, paragraph 32(7).)

(viii) (a) Soil pipes are to be separate from all other drainage. Each W.C. to be provided with a trap with a metal inspection plate and an efficient ventilator connected to the outlet. (Rge. 27(9)(a).)

(b) Soil pipes are not to be less than 4 inches in diameter and are to be so constructed as to to facilitate cleaning and minimise the risk of obstruction ; each pipe to have a direct overboard outfall fitted with a storm valve or valves as required by the Load Line Regulations, unless it is connected with a main sewage outfall by an efficient and hygienic system. (Reg. 27(9)(c).)

(ix) Attention is drawn to Reg. 27(10) which should be adhered to when Reg. 38(2) is relevant, i.e. Asian crew, etc. Reg. 27(10)(b) calls for an arrangement which automatically flushes the pan at intervals, not exceeding five minutes and provides a continuous trickle of water.

Scuppers and wash basin wastes in sanitary accommodation may be linked up with wash basin wastes from sleeping rooms, etc., provided the latter are satisfactorily trapped. Attention

in this respect is drawn to paragraph 25(5) of the Handbook, which requires a trap to be provided with a 3-inch water seal. This is illustrated in Figs. 3 and 4 which show the two most common types of trap, and highlighting the 3-inch water seal. For a ship building abroad, this requirement should be pointed out at an early stage, as standard trap fittings in some countries other than U.K. incorporate a water seal depth of less than 3 inches.

The British Board of Trade invariably require the "U" trap arrangement as in Fig. 3, rather than the sealing device in Fig. 4. The device shown in Fig. 4 incorporates the scupper grating as shown. The Board's objection is that, when the grating is removed for cleaning purposes, the water seal is also removed. For the trap shown in Fig. 4 to be acceptable the arrangement should be such that the water seal is permanent. As such an arrangement would prohibit cleaning inside the pipe it clearly becomes an impracticable proposition.

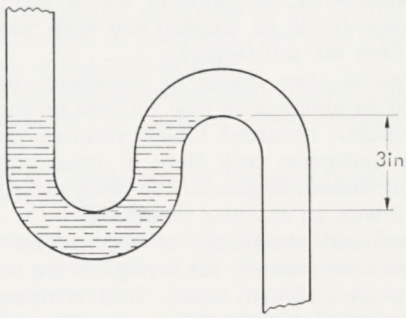



FIG. 3

"U" trap showing 3 in. water seal.

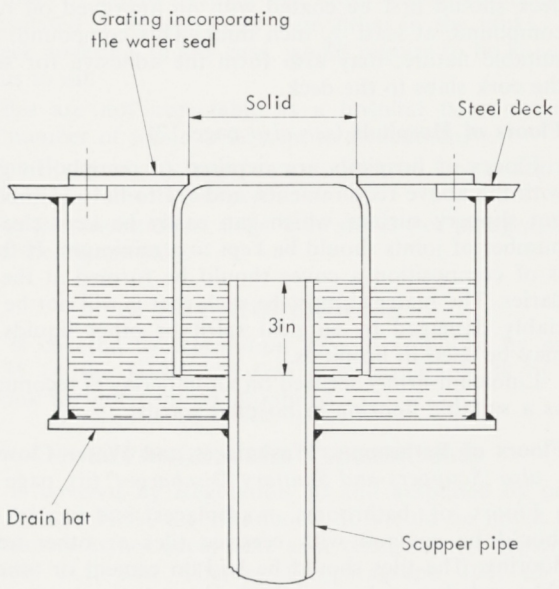



FIG. 4

Showing a scupper grating incorporating a 3 in. water seal when the grating is removed the water seal is broken.

The piping should be tested to ensure tightness and the working efficiency of all valves. It should be ensured that all drainage and discharge pipes have an adequate fall, especially on lengthy collectors. Approximately $\frac{1}{4}$-inch fall per 1 foot length is considered ample.

A large number of today's new ships will be provided with sewage systems. Full details should be submitted, and the Surveyor should satisfy himself fully that the system as installed is efficient.

The requirements of the Load Line Rules as regards "scuppers, inlets and discharges" are also to be complied with, and reference should be made to the Staff Association Paper on the 1966 Load Line Convention by Messrs. Simpson, Bates and Beckwith.

Chapter R of the Society's Rules should be used when plastic pipes are proposed, i.e. "Provisional Requirements for Plastic Pipes". The Surveyor should particularly satisfy himself as regards the connections of plastic pipes, and the support of same. It should be noted that such pipes are to be adequately, but *freely*, supported, the coefficient of thermal expansion for plastics being eight or more times that of steel. Reference to plastic discharge piping is also made on page 30 of the Staff Association Paper on the 1966 Load Line Convention by Messrs. Simpson, Bates and Beckwith.

## 6. ELECTRIC WIRING AND LIGHTING

(See also SAFCON Requirements, page 18)

This is dealt with in Regulation 11, but it should be noted that paragraph (6) of this Regulation has been superceded by Statutory Instrument 1954 No. 1660, The Merchant Shipping (Crew Accommodation) (Amendment) Regulations, 1954. This amendment will be supplied to Surveyors when carrying out a crew accommodation survey.

It will be seen from the Regulations that the units of light measurement are expressed as lumens and foot candles. For a definition of these units the Reference Book "A Dictionary of Science", by Messrs. Uvarov, Chapman and Isaacs, was consulted. A lumen is defined therein as the amount of light emitted per second in unit solid angle by a uniform point source of one candela intensity, i.e. the amount of light falling per second on unit area placed at unit distance from such a source. A foot candle equals 1 lumen per square foot.

The requirements for artificial lighting are further amplified by paragraph 21(b) of the Handbook, and it should be noted that the Surveyor is to satisfy himself as to compliance with the requirements by the use of a direct reading meter, the accuracy of which has been certified by a reliable authority.

Other references to artificial lighting in the Regulations are as follows:—

Galleys: Regulation 28(7).

Hospitals: Regulation 31(10).

Cold Store Rooms: Paragraph 36(7) of the Handbook. (*see also* under "Refrigerated Storerooms", page 17 of this paper.)

References to other electrical items in the Regulation are as follows:—

ELECTRIC FANS: Regulation 12(4) and 31(8) and paragraph 23 of the Handbook.

ALARM GONGS IN COLD STORE ROOMS: Paragraph 36(8) of the Handbook. (*See also* under "Refrigerated Storerooms", page 17 of this paper.)

Electrical equipment and wiring should be effectively isolated from organic foam materials by steel sheet or conduit as appropriate, and there should be an adequate space between the foam and the protective sheet or conduit. (*See* Merchant Shipping Notice No. M.592).

## 7. AWNINGS

This is covered by Regulation 9 (Protection from Weather, etc.), paragraph (k), awnings being required for every ship regularly engaged on voyages to, within, or through, the tropics or the Persian Gulf. Such awnings, however, may be omitted if air conditioning is provided and the omission is taken into account in the design of the air conditioning system. The owners would be required to give a written assurance that the air conditioning system will always be available when the crew are on board.

## 8. DECK COVERINGS AND INSULATION

(See also SAFCON Requirements, page 18)

This is covered by Regulation 7 (overhead decks), Regulation 8 (Flooring), Regulation 9 (Protection from Weather, etc.), and the Second and Third Schedules at the end of the Regulations, and amplified by paragraph 18 of the Handbook.

It will be noted from Regulation 7 that exposed decks over accommodation are to be of steel and sheathed with wood or an approved composition, complying with the requirements of the Second Schedule, or, alternatively, the deckheads insulated to the requirements of the Third Schedule.

An updated list of deck coverings approved by the British Board of Trade is kept in Headquarters for reference when examining plans submitted for approval. Builders abroad may not be familiar with this approved list and any queries regarding same should, therefore, be made as early as possible.

In addition to the above, further Board of Trade Requirements are laid down in the publication "Deck Sheathings for Cargo and Passenger Ships", Circular 1950, published in 1954. The following are extracts therefrom: —

**"Sheathings for the Floors of Crew Spaces**

Linoleum or rubber carpet or tiles of good quality may be used for covering the floors of these spaces. The thickness should not be less than $\frac{3}{16}$ inch for public rooms, passageways and other spaces subject to heavy traffic. For cabins $\frac{1}{8}$ inch may be accepted.

Where the steel deck is flush-plated the linoleum or rubber surfacing may be secured direct to the deck by a suitable adhesive; otherwise the deck plating should be first flushed up with an accepted underlay of minimum thickness of $\frac{1}{8}$ inch.

If it is desired to lay linoleum or tiles or sheet flooring of linoleum-type based on synthetic resins and fillers, at a thickness less than that stated above, particulars should be forwarded for consideration.

These thinner floorings are required to be laid on an accepted underlay at least $\frac{3}{16}$ inch thick. Where the deck is not flush-plated this thickness is to be maintained over the butts and laps of the plating.

The adhesive used for securing linoleum or rubber surfacing to the metal deck, or to the underlay, should be non-corrosive and insoluble in water. If the adhesive is of a type which gives off inflammable vapour, while being used, it should be ensured that all necessary precautions are taken against the risk of fire.

Trowel-laid floorings of suitable materials may be used. Examples of this type of flooring are those based on rubber latex, or synthetic resins, mixed with cement and various fillers. Full particulars of such materials should be submitted for consideration.

In the case of floorings of the magnesium oxychloride type an anti-corrosive coating at least $\frac{1}{4}$-inch thick is to be first applied so as to cover completely the metal deck to protect the plating against possible corrosive action. Such coatings are to be of types accepted by the Ministry.

All composition floorings in crew spaces should be rounded up where the floor meets the boundary bulkhead.

Except in the case of under sheathings of magnesium oxychloride type, or where the deck forms the crown of an oil fuel tank, formal acceptance by the Ministry is not required for anti-corrosives and adhesives which are not now included in the Ministry list of accepted sheathings. Surveyors should be satisfied that such materials and their application are satisfactory.

Floors of crew spaces or passenger spaces, which are exposed to appreciable heat or cold on the underside, are to be suitably insulated. Unless adequate insulation is fitted on the underside, cork slabs or other suitable insulating material should, in general, be fitted on the deck and then covered with an accepted sheathing.

Trowel-laid sheathings of the wet-mix type are not altogether satisfactory for laying on the top of cork slabs as they are liable to crack. If it is desired to use such floorings, the cork should be completely covered with a waterproof sheeting, and not less than $\frac{1}{2}$ inch of flooring should then be laid. Alternatively, the cork should be flushed-up with an underlay as necessary and then covered with linoleum.

Where the deck forms the crown of heated oil tanks the deck should first be coated with an approved oil resisting compound, at least $\frac{1}{16}$ inch thick. This compound, if of a suitable nature, may also form the adhesive for securing the cork slabs to the deck.

**Floors of Hospitals** (*see also* page 17)

Floors of hospitals are required to comply, in general, with the above requirements, and are to have a smooth but not slippery surface which can easily be kept clean. The number of joints should be kept to a minimum. If the floor is of composition a cover should be formed at the boundaries. The material must be such that it will not be appreciably damaged by surgical spirit or other liquids which may be used in hospitals.

Linoleum firmly secured on an underlay is recommended as a suitable flooring in hospital wards.

**Floors of Bathrooms, Washplaces and Water Closets** (*see also 'Scuppers and Sanitary Discharges'* (ii), page 18)

Floors of bathrooms, washplaces and water closets should be covered with ceramic tiles or other accepted flooring. The tiles should be laid on cement or other suitable underlay and coved at the boundaries.

It is recommended that the floors of these spaces should be of a light colour.

Where a stateroom or cabin has its own bathroom, washplace or water closet adjoining, and is intended for the use of not more than two persons, the same type of flooring

used for the cabin may, if desired, be fitted in the bathroom, washplace or water closet.

**Sheathings on the Crowns of Crew Spaces which are Decks Exposed to the Weather**

Sheathings on such decks are to be of an approved type and are required to provide thermal insulation at least equivalent to that provided by a $2\frac{1}{4}$-inch wood deck. For this purpose the thermal conductivity of wood may be taken as one British Thermal Unit per square foot per hour for 1 inch thickness and 1° F difference in temperature between the faces.

If the sheathing is in more than one layer a sheet of waterproof felt, or other material suitable for the purpose, is to be laid between the layers, or other effective arrangements adopted, so as to ensure that if the upper layer cracks the lower will not become saturated in course of service.

For bituminous materials a $\frac{1}{2}$-inch bitumen expansion joint is to be worked at each edge of the sheathing where it abuts deck houses or coamings, and this joint is to be covered with a coved asphalt fillet.

Sheathings containing magnesium oxychloride are not considered suitable for use on decks exposed to the weather.

**Sheathings on the Underside of Weather Decks which are Crowns of Crew Spaces**

The material should generally be applied direct to the deck so as to avoid harbourage for dirt and vermin and to obviate condensation as far as may be practicable. Particulars of the method of fixing must be submitted for approval."

Further notes as regards some known Board of Trade requirements as regards deck coverings and insulation are as follows:—

(i) Floors of cabins over oil fuel tanks would require to be insulated if heating coils were fitted in the tanks. The deck covering, in any case, would require to be impervious to oil.

(ii) Tiles are not acceptable as a hospital floor covering ("number of joints to be kept to a minimum").

(iii) For floors in dry provision storerooms (*see* paragraph 35(3)(a) of the Handbook).

(iv) For the insulation of ships' cold stores (*see* paragraph 37 of the Handbook).

## 9. DRY STOREROOMS

This is covered by Regulation 29 and amplified by paragraph 35 of the Handbook (*see also* paragraph 38 of the Handbook for notes on rat proofing.)

## 10. REFRIGERATED STOREROOMS

This is covered by Regulation 30 and amplified by paragraphs 36 and 37 of the Handbook. It should be noted that methychloride is not acceptable as a refrigerant (Chapter G, paragraph 111, and Chapter N, paragraph 105, of the Society's Rules and Ministry of Transport Notice No. M.408.)

The insulation of ships' cold stores is extensively covered by paragraph 37 of the Handbook. Reference to overhead decks is also made under "Deck Covering" on page 26.

If polyurethane foam and other organic foam materials are to be used as the insulant they should be covered with a suitable incombustible protective facing. Such storerooms should be sited as remotely as possible from sleeping accommodation, and places of high fire risk. Details of the construction and location of the storerooms will require to be submitted (*see* Merchant Shipping Notice No. M 592).

Special attention should be made to the requirements for lighting which states that each insulated room should have a separate electric light of robust construction with an outside switch and a pilot light.

It should also be noted that for use in the event of a person being inadvertently locked in the cold chambers a watertight switch or push button is to be fitted in each room and connected to an alarm gong. The requirements are fully stated in paragraph 36(8) of the Handbook. This alarm system, together with the lighting arrangements, are to be tested to the Surveyors satisfaction.

*See also* "Ventilation", page 10.

## 11. NATURAL LIGHTING

This is dealt with in Regulation 11, and Statutory Instrument 1954 No. 1660, The Merchant Shipping (Crew Accommodation) (Amendment) Regulations, 1954. Regulation 11 requires that all parts of the crew accommodation, other than pantries, laundries, drying rooms, lockers and store rooms, be provided with adequate natural light. The Regulation also states that sanitary accommodation and passageways may be exempt from this requirement if compliance is unreasonable or impracticable in the circumstances. This is very often the case, and adequate artificial lighting should then be provided in lieu. Adequate natural light, as required in a sleeping room, mess room, recreation room or hospital ward, is defined as being sufficient to enable an ordinary newspaper to be read by a person of normal vision at any point in the room, being a point available for free movement, during day time and in clear weather. The Surveyor is to satisfy himself to such provision.

Every sidescuttle in a sleeping room, mess room, smoking room or recreation room is to be capable of being opened, and is to be at least 12 inches in diameter. It should be noted also that all sidescuttles (and deadlights where required by the Load Line Rules) are to be in accordance with or equivalent to British Standards 3024:1966.

The requirements for natural lighting are further amplified by paragraph 21(a) of the Handbook. Sub-paragraph (2) states that natural lighting should normally be provided by windows, sidescuttles or skylights. However, windows are to be in accordance with, or equivalent to, British Standard 3925:1965, which does not legislate for windows in first-tier superstructures. The requirements of the Load Line Regulations prohibit the fitting of windows in first-tier superstructures and first-tier deckhouses on British ships.

The position and details of all sources of natural lighting should be clearly indicated on a plan and submitted for approval. This may be included on the general layout plan, or on a separate plan according to the shipbuilders particular practice.

Other references to natural lighting in the Regulation are as follows:—

GALLEYS: Regulation 28(5) and (6) and paragraph 34(6) and (7) of the Handbook. Regarding the requirements for the provision of horizontally divided weather doors where galleys are situated on an open deck, care should be taken not to contravene the requirements of the Load Line Rules when

such doors either protect companionways, or are situated in a superstructure.

HOSPITALS: Regulation (6). *See also* "Protection against Mosquitoes" Regulation 33 and paragraph 41 of the Handbook. *See also* page 10 of this paper.

## 12. PAINT SPECIFICATION

(See also SAFCON Requirements, page 18)

A specification is to be submitted which should comply with the requirements of Regulation 14 and paragraph 26 of the Handbook. Paragraph 39(6) of the Handbook should also be noted as regards the painting of hospitals.

## "SAFCON" REQUIREMENTS

As previously mentioned, the survey of crew accommodation overlaps the safety construction survey, the requirements for British ships being specified in the Merchant Shipping (Cargo Ship Construction and Survey) Rules 1965. For Classification purposes this is covered by Chapter F, Part 2.

When a Surveyor is carrying out a Crew Accommodation Survey on behalf of the British Board of Trade, the Board require that details of (a) "Structural Fire Protection" and (b) "Means of Escape" should be submitted on the crew accommodation file, i.e. considered as part of the crew accommodation survey.

When a Crew Accommodation Survey is being carried out by the Society at the request of the owner, the above plans are to be submitted as usual to the Fire Section of the International Conventions Department. The actual survey at the ship, to ensure compliance with the approved plans, will obviously be carried out during the Crew Accommodation Survey. During the survey the Surveyor should ensure that all type "B" bulkhead panel joints are a close fit.

One of the problems of detail which the Surveyor will meet during the survey will be that concerning the penetration of fire bulkheads by pipes, ventilation trunks and electric cables. The following guidelines are suggested:—

(i) **Penetration of Type "A" Bulkheads**

For pipes and ventilation trunks a welded steel collar should be fitted. The collar should be the same thickness as the bulkhead. For cables a watertight fireproof gland is necessary.

(ii) **Penetration of Type "B" Bulkheads**

The clearance between pipe/trunk/cable and the bulkhead should be kept to a maximum of 1 inch, and fitted with incombustible packing to prevent the passage of flame and smoke. Collars should be fitted, where necessary, to restrict the clearance to 1 inch.

(iii) **Penetration of Bulkheads by Plastic Pipes**

When passing through types "A" and "B" bulkheads a steel penetration piece should be fitted for 18 inches each side of the bulkhead.

A large number of the above penetrations, through types "A" and "B" bulkheads, will be above the level of the ceiling. The arrangements at such penetrations, therefore, require to be seen before the erection of the ceiling.

It should also be noted that ventilation jalousies and similar openings are only permissible in the lower portion of doors and not in the corridor bulkheads.

Ventilation trunking should not, if possible, penetrate the machinery casing. If the trunking does in fact pass through the machinery casing, details should be forwarded at an early stage for examination by the Fire Section of the International Conventions Department. The trunk scantlings may require to be increased in such cases, or suitable fire dampers may be required on the outboard side of the casing with instructions to the effect that they are to be kept closed in the event of a fire in the machinery space. On several British ships known to the Authors, where ventilation trunks pierce the machinery casing, the Board of Trade required that the minimum thickness of trunk plating should be 0·2 inch for a trunk 30 inches in width or diameter, and 0·125 inch for 12 inches or less. (Intermediate widths by interpolation.)

It should also be noted that the SAFCON Rules require deck coverings within accommodation spaces on the decks forming the crown of machinery and cargo spaces to be of a type which will not readily ignite. All deck coverings approved by the British Board of Trade as satisfying the Crew Accommodation Regulations in these positions also satisfy this SAFCON requirement.

**Piping Systems and Domestic Boilers, etc.**

The Safety Construction Regulations require that the Safety Construction Survey is to be such as to ensure the arrangements, materials and scantlings of boilers, and other pressure vessels and their appurtenances, are in all respects satisfactory for the service for which the ship is intended.

The Society's Rules have never included domestic boilers having a working pressure of 50 lb. per square inch or less with a heating surface of 50 square feet or less, and domestic equipment not essential to the operation and safety of the ship. Such items are precluded from the Classification Rules on the grounds that it is almost a practical impossibility for a Surveyor personally to examine and test every vessel working at low pressure on board ship, and that owners must accept some responsibility for domestic equipment which they install. This point has been appreciated by a number of countries, as far as the Society's issuance of a SAFCON Certificate is concerned.

However, it is the opinion of the Authors that when the Society is requested by an owner to carry out a Crew Accommodation Survey some responsibility for these vessels should be accepted.

The Authors' recommend the following procedure:—

(i) Pressure vessels for use in an enclosed piping system to be submitted for approval of scantlings and test pressures. These to be forwarded with the Crew Accommodation Plans to the International Conventions Department, for onward transmission to the Machinery Designs Appraisal and Plan Approval Department for their comments. The Surveyor at the ship would then examine such pressure vessels for compliance with the approved plans and test to the required pressure.

(ii) For the remaining items of domestic equipment, the Surveyor need not personally examine and test every such item. He should satisfy himself, however, that this has been done by competent persons such as the installation engineers or the shipbuilders, by sighting copies of the appropriate certification.

**Electric Wiring and Lighting**

Sub-paragraph (5) of the Crew Accommodation Handbook defines the suitable alternative system or source of power

required by Regulation 11(5). Care should be taken, however, to comply with the Safety Construction Rules and the Society's Rules as regards emergency source of electrical power in cargo ships.

The Safety Construction Rules require emergency lighting in all crew alleyways, stairways and exits, and the requirement for the source of such emergency lighting is much more onerous than provided for in the Crew Accommodation Rules. The source of emergency power for these particular items, as well as that for the remainder of the crew accommodation, should be clearly indicated on the plan submitted for approval.

The requirements of the Safety Construction Rules and the Society's Classification Rules as regards precautions against shock, fire and other hazards of electrical origin will be covered separately during the normal course of the Classification Survey.

**Paints, etc.**

The Safety Construction Regulations and Chapter F of the Society's Rules require that in accommodation spaces, paints, varnishes and similar preparations having a nitro-cellulose or other highly inflammable base are not to be used. This should be stated on the Paint Specification submitted for approval (*see* "Paint Specification", page 18).

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# Discussion

on

Messrs. J. R. G. Smith's and J. W. Barron's Paper

# THE SURVEY OF CREW ACCOMMODATION

Paper No. 4. Session 1970-71

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# Discussion on Messrs. J. R. G. Smith's and J. W. Barron's Paper

# THE SURVEY OF CREW ACCOMMODATION

## Mr. L. BECKWITH

The opening gambit at the reading of papers such as this is usually that as the paper is mainly factual there is very little to add. I am sure that you will agree with me that in this case this is not true. This paper is, perhaps, only "the tip of the iceberg" and I would hope that the ensuing discussion, both verbal and written, will unearth some of the vast amount of information on the subject which must be available, in outports or in the private files of individual Surveyors.

This work is another of the areas into which the Society has been drawn in recent years. As the Authors state, with the growing number of British ships being built abroad, the Society has become increasingly involved in Statutory Surveys on behalf of the Board of Trade, or Department of Trade and Industry as it is now known. Consequently a need had arisen for a paper on the subject which would be termed "a Surveyor's Guide to the Regulations". The Authors also state that they are no experts on the subject and indeed go further in stating that the Society's collective experience is comparatively limited. Mr. Smith, I know, was involved in a number of such surveys during his service abroad, and Mr. Barron has been on the receiving end of Crew Accommodation plans submitted for approval for some years now, so between them they have a fair amount of experience.

From this experience they have drafted a document which should save many hours of midnight oil burning by the Surveyor presented with a Crew Accommodation Survey for the first time. Anyone who has attempted to unravel the mysteries of official regulations, particularly unfortunately British Regulations, and has travelled from regulation to schedule and back again will appreciate the problem. The way that the various items are listed and explained in the paper under particular headings such as general layout, ventilation, etc., should be found most helpful.

One of the assets of a paper of this kind, however, is the possibility of "feedback" from our colleagues in various parts of the world. Many of these Surveyors must have had experience of such surveys and may have developed survey methods or test procedures which, in addition to being of interest to other colleagues, would add to the information on the subject being collected in London Office. The forwarding to London of copies of correspondence on particular aspects of interpretation by the Board of Trade would also help in this respect.

Mention has been made of the two major sets of regulations in use. It seems to me that many of the major Maritime Administrations must have their own regulations and/or instructions to their Surveyors on this subject. It would be most useful if copies of any information could be forwarded to London to add further to the amount of information available.

The main theme of the paper is surveys on behalf of the B.O.T., but there is an increasing requirement for surveys on behalf of owners to certify that Crew Accommodation complies with these regulations and, in addition, Surveyors are frequently being appointed to act on behalf of owners to certify specification items of which Crew Accommodation could be one. There is obviously a potential increase in the Society's work in this field and this paper should be most valuable to Surveyors asked to carry out such work.

Certain procedures have been suggested and I am sure that they will be gratefully received, but on the other hand I feel that there will be similar procedures more suited to a particular country, port or shipyard. I am sure that the Authors would agree that it would scarecly be possible to lay down standard procedures, and in fact that rather than the builder fitting the Surveyor's test requirements into the building schedule it may very well be the other way round.

There are many points of detail in the paper which other colleagues will wish to comment upon but I would like clarification on two small matters.

On page 6, under the heading "General Layout Table (1) General Notes", it is stated "hardwood doors would be acceptable from the crew accommodation point of view provided they were of adequate strength and construction, etc.

I think some mention should be made of fire regulations in this connection as I believe that the B.O.T. and perhaps some other administrations will not accept wood doors in certain positions.

On page 7, Table (2), I note that first of all a high standard is set of separate messrooms for P.O's and ratings, then the standard is lowered by allowing P.O's and ratings of the same department to share a messroom. The standard is lowered even further by specially considering a single messroom for all P.O's and ratings of deck and engine departments together with catering staff. Who decides on such reductions of standard? Is it the Administration concerned, or do the Seamen's Union have to be consulted?

Finally, I would like to thank the Authors for their efforts in producing this paper and hope that they will achieve their object by promoting a fruitful discussion.

## Mr. J. M. BATES

The Authors must be congratulated in presenting this paper on a subject which is new to the Staff Association, particularly in view of the enthusiasm and effort which went into its preparation.

The purpose of the paper is to give colleagues some guidelines in conducting a type of survey of which they may have little or no experience. At the same time it is felt that the opportunity could be taken to relate some of the background behind the regulations governing the arrangement of crew accommodation. The comments now made are simply in the nature of suggestions to the Authors to supplement the contents of the paper and widen its scope.

The International Labour Organisation (I.L.O.) at a Conference held in 1949 produced Convention No. 92 dealing with matters affecting crew accommodation. However, unlike other Maritime Conventions such as S.O.L.A.S., Load Line and Tonnage Conventions, it did not include instruments whereby it would become a set of Regulations recognised internationally after it had been signed, acceded to or accepted by a prescribed number of participating countries. It seems that it was left to any Administration sufficiently interested to apply

the recommendations of the Conference on a voluntary basis. It would be useful to know which countries in fact apply the I.L.O. Convention, and indeed how fully they apply it.

We know, of course, that this Convention is applied by the United Kingdom and that the published U.K. regulations are more detailed than the recommendations of the Convention. They are referred to in the paper as British Crew Accommodation Regulations, and on this point a warning must be given. Many builders and owners beyond these shores will interpret "British" regulations as being common to all members of the Commonwealth, whereas this is regrettably not the case.

In a recent instance of a ship building in Europe, the Society had been requested to carry out the survey of crew accommodation in accordance with the British regulations. The ship was first intended to be registered in Singapore whose government applies the U.K. regulations, but fairly soon after the owners decided to register the ship in Australia instead. Both countries are generally described as "British" but the Australian crew accommodation regulations differ particularly with regard to the interpretation affecting the use of Type "A" and Type "B" Fire Bulkheads as described in S.O.L.A.S. 1960 Convention. If the change of registration had been decided at a late stage of building there could, therefore, have been expensive repercussions so far as the builders and owners were concerned. As a further complication, whereas the Government of Singapore have authorised the Society to act on its behalf in respect of these Surveys, the Australian Government has not.

The Society could well perform a service to builders and owners in advising them of these pitfalls whenever possible, even if the Society is not directly concerned in the conduct of the Survey of Crew Accommodation.

The Authors state on page 4 that the Society is unlikely to be required to carry surveys on certain types of ships. Cases can very well occur in ships of less than 3,000 tons, but they would probably come outside the scope of the paper and would be subject to special consideration.

There is a note on page 6 under the heading of "General Layout Table" which states that "all crew accommodation other than storerooms is to be situated above the Summer Load Water Line". It should be stressed that so far as the U.K. Regulations are concerned the penalty for placing crew accommodation at too low a level would result in loss of draught, and consequently deadweight, and this should be impressed on designers whenever possible to avoid repercussions which could be serious to the builder or to the owner, if such circumstances were discovered by the Administration concerned at too late a stage. This is a service which the Society can perform even though not directly concerned. It is the practice in International Conventions Department to warn builders or owners whenever it is found from information received that such a situation could occur, particularly when owners are seeking deeper loading in the case of existing ships. They are then advised to consult with the Administration concerned. Some notes on this subject have been included in Appendix V of the paper on the 1966 Load Line Convention presented during the 1969–70 session of the Staff Association. It would have been wiser to refer also in this Appendix to the "U.K." rather than to the "British" Merchant Shipping Regulations. A sad case did occur affecting a ship building in a particular country for owners in a neighbouring country. This ship was of the OSD/CSD type and built before the Tonnage Mark system was thought of. Whereas the crew accommodation was situated above the Summer Load Water Line in the OSD condition, it was submerged by several feet in the CSD condition. No useful warning could be given from London as the situation became apparent only when the Rpt. C.11 was received some two or three weeks before completion. The National Administration concerned was not even then aware of the effect of the deeper draught as the ship was completing at the smaller OSD draught. A compromise was eventually reached by limiting the maximum draught to a specified distance below the lowest sidescuttle. The owners nevertheless suffered a serious loss of draught and the builders themselves must have suffered financially at least.

In Table 5, divisions between spaces are catalogued as Bulkheads A, B or C. Although these types of bulkheads are defined in the Table, it is suggested that they be assigned a different coding to avoid any ambiguity arising from the S.O.L.A.S. 1960 requirements for Type "A" and Type "B" bulkheads also referred to on page 18.

It is stated in the last sentence of the third paragraph under the heading of "Natural Lighting", on page 17, that the requirements of the Load Line Convention prohibit the fitting of windows in first-tier superstructures and first-tier deckhouses on British ships. The latest ruling from the Department of Trade and Industry prohibits their fitting in first-tier deckhouses only when such erections contain otherwise unprotected openings leading below the freeboard deck

If the deck opening within the deckhouse is itself protected by a companion with a door and sill, as if it were exposed, windows may be fitted. Consideration must be given, however, to each individual case with regard to the protection of crew. The prohibition of windows in superstructures (as defined in the Load Line Convention) in Position 1 applies to ships of any flag.

### Mr. C. D. SNEDDON

Anyone tackling a Crew Accommodation Regulation job knows what a maze of requirements have to be met. It is some time since I did any myself, but a good deal remains familiar and, from recollection, involved a great deal of writing of endorsements of considerable length on minor details.

The Authors' paper is undoubtedly extremely helpful in smoothing the Surveyor's path through this jungle, and I am certain will be greatly appreciated at the Outports. It attempts to, and does, put things in logical sequence with adequate cross-referencing for guidance. It is a welcome addition to the Staff Association papers.

On particular aspects of the paper, on page 4 the list of vessels excluded from consideration does not mention fishing vessels. This is probably an oversight as Rule (2) of the Board of Trade Crew Accommodation Regulations applies to every British ship registered in the U.K. not being a fishing *boat.* It is fairly clear this class of vessel cannot be expected to comply with requirements for ocean-going ships and, in fact, reference to the Cargo Ship Construction Rules shows fishing *vessels* to be exempt from the construction requirements for sea-going ships. I am not sure whether a legal difference exists between the term "boat" and "vessel" but this might be clarified.

At the same time their exclusion from consideration might be queried on the score that fishing vessels can be of various categories from, say, the 150 ft. ordinary trawler up to the 3,000 tons gross factory trawler also processing fish meal, and the 450 ft. mother ship of 10,000 tons gross for flotilla fishing. Some of these ships may be at sea 60 or more days, therefore it would seem scarcely reasonable to exclude them. The Board of Trade view on this might be given.

On page 6, Note 7, of the General Lay-out Table deals with ready means of escape to the lifeboat embarkation deck. As these arrangements come under Chapter D of the Rules I would like to know who checks these. If done in I.C.D. I would expect that there should be alternative means of escape from crew's quarters such that a person can turn either left or right in a corridor and still reach a stairway. At one time escape scuttles in the shell of 16 in. to 18 in. diameter were accepted for emergency use, but while this might have been feasible with a crew member wearing the old standard life-jacket, the new waistcoat type makes the prospect even more doubtful. One will see in the U.S. Coastguard Regulations for passenger ships that "dead-end" corridors, i.e. those from which there is only one way out, should not exceed 40 ft. in length and possibly a similar concession may operate in the case of British ships, of which the Authors' might be aware.

On page 9, in Table No. 5, the only requirement in the Crew Accommodation Regulations for accommodation situated on the crown of a space in which oil may be carried in bulk is that the deck should be oiltight. I think attention should be drawn to D.4010 of the Society's Rules which requires a cofferdam to be arranged between cargo oil tanks and accommodation spaces (or spaces containing electrical equipment except where only lighting fittings of flameproof type are fitted complying with M.1604).

On page 11, I would agree with the Authors' figures for nett area of jalousies but would mention that for passenger ships the proposed new regulations restrict the area to 78 sq. in. By the strict letter of the law in the S.O.L.A.S. Convention 1960, there are no requirements covering the fire integrity of cabin doors on cargo ships and when this point was first raised with the B.O.T. the advice received was to the effect the doors could be of any material whatever, but at least this has been revised to requiring permanently attached doors or shutters.

Deck coverings, referred to on page 16, has always been a difficult subject from the S.A.F.C.O.N. angle of fire safety due to the vagueness of the standard to be applied. What is said on page 18 in this respect that all deck coverings approved by the B.O.T. will meet S.A.F.C.O.N. reuirements is, of course, only correct for British ships. It is not to be taken as universal approval by any means. This subject has been fairly thoroughly gone into by the I.M.C.O. Sub-Committee on Fire Protection who have evolved a test procedure for deck coverings exposed to fire from below (which is the main hazard at deckheads of machinery spaces and cargo spaces). Briefly, a 24 in. square piece of plating, 5 mm. thick, with the deck covering above is to be placed horizontally over a furnace in which the temperature is controlled in accordance with the standard time/temperatures curve. The test is for 15 minutes. A pilot flame is to be passed over the specimen at one minute intervals after gases are first seen to be evolved. Any flaming which breaks out and continues for more than 10 seconds is to be considered as continuous flaming and would therefore condemn the specimen. There are also additional considerations that the evolution of smoke should not be excessive and spot checks should be made on the toxic products given off. For determining the ignitability of deck coverings from a fire source above the covering, it is recommended a simple ignitability or flame spread test should be applied.

On page 17, the Authors make reference to the hazards of polyurethane foam in refrigerated storerooms. Unfortunately, the "M" notice referred to does not cover crew space comfort insulation which can be equally if not more hazardous if certain plastic foams are used, in particular, polystyrene. The nature of this is such that it vaporises very readily in the presence of heat and a hole can be bored through it using a glowing cigarette. If actually ignited, however, it burns extremely rapidly. We have in the past attempted to get this material rejected for crew spaces under the rule that paints, varnishes and similar preparations having a highly inflammable base should not be used in accommodation spaces, but that is rather twisting the regulations.

We have, in fact, a test certificate from a British laboratory stating that the material exhibits nil flame-spread properties. This is wholly false and arises from the unsuitability of the list for flame-spread which was applied to it. It would be advisable to check all materials against their test certificates.

In regard to paints, I.M.C.O. have also had this matter under consideration. There is a wide variation in standards of flame-spread as evidence from tests carried out on six specimens for the purpose of comparing national criteria. Two countries rejected five of the six coverings as unacceptable, and one country accepted them all as satisfactory. An I.S.O. technical committee is working towards the formulation of an internationally acceptable test procedure.

There is a good deal more that could be said about moves on foot to raise the whole standard of S.A.F.C.O.N. requirements in ordinary cargo ships, to protect tankers against fire hazards, to prohibit accommodation located over the cargo tanks of chemical tankers, etc., which will alter a good deal of what is contained in the paper but these will not materialise as firm requirements for some considerable time and in no way detracts from the excellent survey given by the Authors.

### Mr. G. COGGON

During my service abroad I had one of these surveys to do. As, I believe, is usual in these cases this was accompanied by other surveys outside the normal run of a Surveyor's duties. I had the Passenger Safety Survey, Simla Rules, Tonnage Measurement and Cargo Handling Gear survey and tests. This entailed a lot of study of relatively unfamiliar subjects in one's own time.

In the case of the Crew Accommodation Survey the only help I received from London was the Statutory Instrument and Hand Book which I already had but had never read. On reading them I found them to be every bit as interesting as I had always suspected.

In what was normally a busy district there was not much time for studying Rules, and I well remember finding, among other things, that the draw-off taps in the washrooms had to be spring-loaded, only after swivel-type taps had been fitted throughout the accommodation.

If I had had this paper at that time my task would have been much simpler and my survey more efficient. Therefore, I would like to thank the Authors for their paper; it is a document which will only be fully appreciated by Surveyors when they get one of these surveys to do.

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I think it is a point worth considering that these surveys are usually carried out on ships building in yards abroad where the British Rules and practises are not known. The builders often require guidance on their application and turn to the Lloyd's Surveyor. The paper will provide a ready reference to enable him to render such assistance quickly.

In the country where I was stationed I am sure it was not normal practice for the national authority surveyor to survey

crew spaces in detail as laid down in this paper and the yard were surprised at the tightness of our control. It would, therefore, have been helpful at an early date to present to the management a copy of the tabular list of tests and inspections given on page 5.

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In Section 10, entitled "Refrigerated Storerooms", on page 17, mention is made of the use of polyurethane and other organic foam insulants, and reference is made to Merchant Shipping Notice No. M.592. I attended a meeting at the B.O.T. when the draft of this notice was discussed and the B.O.T. officials present were adamant that the use of such materials could under no circumstances be permitted for the thermal insulation of crew and passenger accommodation. These materials are highly inflammable with a very rapid flame-spread often in excess of 100 ft. per min. They release enormous quantities of heat temperatures of 1000°C being generated in the initial stages of burning and large volumes of toxic fumes which could rapidly overwhelm an unsuspecting crewman trying to fight a fire with the aid of a portable extinguisher. Would the Authors please give the Society's attitude to the use of these materials in the linings of crew accommodation spaces and ceiling tiles of rigid polyurethane or polystyrene.

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I believe the use of bolted couplings in sanitary pipes in provision stores in American ships is prohibited by the U.S.C.G. Rules to prevent the contamination of stores. Could the Authors tell us of any similar requirement in ships under the Society's survey.

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On page 18, under the heading "Penetration of Type 'A' Bulkheads", would the Authors state why the gland at the passage of cables is required to be watertight as the bulkhead itself is not generally required to be watertight. The word fireproof should not be used when referring to bulkheads and their appurtenances. "A" Class bulkheads are referred to as fire resistant and "B" Class bulkheads as fire retardant.

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Finally, I would like to ask whether it is automatic that, on ships such as Liberian, where we are assigning the tonnage, we also do the survey of crew accommodation and if we do not do it, who does?

### Mr. A. C. CHOUDHURY

Comparatively little time and thought has been devoted in the past to the design of crew accommodation. This is not surprising because the owners are mainly concerned in designing cargo ships for maximum profit. Secondly, trade conditions are different in different countries and therefore the acceptable standard of crew accommodation also varies, depending on a number of factors—such as the availability of finance, demand for low initial expense and limited cost of maintenance.

In addition it is not possible to have uniform design practice because of the different standards of living encountered in developed and developing countries. Ship owners flying the flags of developing nations can get away with spending far less money by providing less comforts and smaller living area, because

(1) superior faclities are not always expected by the crew, and

(2) prevailing unemployment gives greater choice in recruitment.

In such conditions the naval architect has to face these realities. He can design complicated and sophisticated crew accommodation, but he has to think if the buyer will pay for it. Since the shipping industry in developing countries has to make do with small margins of profit and has a proportionately large number of tramp ships, funds are limited, unless Government subsidy is available. It is for this reason that luxurious crew accommodation is not realistic.

In advanced countries the opposite is the case—the owners have money, the employees are organised in unions and more demanding, and subsidies are available. For such reasons, the American unions for example have been successful in getting very comfortable living accommodation for the crew in their country—which makes space on board ship a very serious problem for the owners. These companies therefore pay much attention to reducing maintenance costs by automation and mechanisation on board.

Bearing in mind the above general comments and the fact that the Society is involved with parties who look at the question from opposite points of view, I have put down some thoughts which crossed my mind on reading the paper written by Mr. Smith and Mr. Barron:—

1. The suggestion that I.L.O. Regulations being vague, the British Regulations of 1953 should be followed (pages 1–4). It is the practice of the Society to criticise and its criticism, based on wide experience and observations relating to the requirements of various countries, would always command respect. Unless the competent authority or the owner specifically require otherwise, would it not be better for the Society to give its advice on merit, rather than to automatically follow what is laid down in the British Regulations?

2. Position of crew accommodation amidships or aft (page 6). There are conflicting factors in view of recent trends in design particularly with regard to super-tankers. Rethinking is necessary, for example with respect to the location of the wheelhouse in relation to the sight forward over the bow. Recently built Lash and Seabee barge carriers indicate positioning the crew accommodation forward to a great extent, therefore modification to the rules might be anticipated.

3. Layout of Messrooms (Table page 7). Maintenance costs will be reduced and more space available if the class distinction between the crew mess and petty officers' mess is eliminated as is the practice in the U.S.A.

4. In view of the importance of reducing costs, standardisation of furniture for each country may be a useful procedure to follow.

In conclusion I would like to quote Dr. S. J. P. Thearle, who was Chief Ship Surveyor in 1914. He said: "The Society comes between two parties who look at the ship from opposite points of view. These are the shipowner and the underwriter, the builder and the shipowner, the buyer and the seller. The Society has to do justice to each and all of these". In the matter of approving crew accommodation also this excellent principle has to be kept in mind.

Mr. Smith and Mr. Barron have given us an excellent paper and should be congratulated, especially because this subject has been up to the present time almost ignored in our technical literature.

### Mr. W. N. G. McCULLOCH

The Authors have taken a rather narrow view of their subject, focusing their attention only on the printed regulations applicable to new construction of U.K. registry with the exception of the types enumerated on page 4.

This is a great pity since the Society has been involved for many years in the survey of crew accommodation of British and non-British ships, as an integral part of Tonnage Admeasurement, and for more than ten years in carrying out Specification Services duties, which include surveying the accommodation, irrespective of nationality or the type of ship. We are also authorised to survey and report upon accommodation in Swedish flag ships as part of that Government's quadrennial survey for seaworthiness (Circular 2131).

In view of the Society's greater involvement in the survey of accommodation than that indicated by this paper, I think a general note on the *raison d'être* for crew accommodation rules would be useful, particularly to our field colleagues who frequently have to make practical interpretations of the Rules based on sound common sense.

The Net or Register Tonnage of a ship is a measure of its money-earning capacity and, as such, excludes the tonnage of those spaces appropriated to the use of the crew. Harbour and other dues, which are levied on the shipowner, are based on its money-earning capacity, and it is therefore in the owner's interest that the figure of net tonnage be as low as possible.

Consideration for hygiene and the comfort of the crew was, in general, sadly neglected by the shipowner until about the turn of the present century when owners were finally prompted by the introduction of legislation to maintain established minima or risk the penalty of having the tonnage of crew spaces added to the Net Tonnage (non-deductable through non-compliance).

Since concern is for hygiene and comfort it is understandable that standards of accommodation are required for such items as headroom, floor area, volume, heating, lighting, ventilation, drainage; constructional details should be such as to discourage vermin, and paints, compositions, etc., should be non-injurious to health and should facilitate maintenance; location of the accommodation and its protection from weather, heat, moisture, etc., all require detailed consideration.

Among the maritime nations of the world the British nation has been foremost in establishing detailed technical minima and the Merchant Shipping (Crew Accommodation) Rules 1953, together with the explanatory Handbook for the Guidance of Shipowners published in the same year, and the Government's "Instructions as to the Survey of Masters' and Crew Spaces" are used internationally for guidance where no national regulations exist, in addition to their being strictly applied to U.K. registered ships.

The Authors have omitted to mention a very important aspect of the certification of accommodation in the marking of individual spaces when these are found to comply with the Regulations (Regulation 15), and I should like the Authors' interpretation of paragraph 3 of this Regulation, ". . . or otherwise marked in an equally permanent manner".

If we are to become more deeply involved in the future in the survey of crew accommodation in U.K. ships, I would like to know the Authors' opinion of how we would handle requests made under Regulation 35(e) and (f), keeping in mind that our function as Surveyors to Lloyd's Register is the protection of the many interests represented on our Committee of Management.

I should also like to know if the Society's forms T1 and T2, used for the computation of tonnage and reporting crew accommodation details in non-U.K. ships, are still in use and which regulations are used to check these details.

The construction and outfitting of accommodation is progressive from the lowest accommodation deck, and the survey must be conducted in the same way. Records of the survey are kept in the Surveyor's Journal and these may also be kept on separate record sheets when it is important to see the progress of the survey at a glance, e.g. when carrying out owner's supervisory duties and periodic progress reports are required. Survey record sheets are normally made out separately for each deck and the progress of each item, piping, insulation, deck covering, etc., is recorded as a percentage of the total. The Authors' proposed survey chart is a useful diagrammatic indication of the items involved but has the probability of being incomplete in a particular case—hose testing of bulkheads and sidescuttles, flooding tests of shower spaces, the marking of spaces, etc. The detailed layout of a survey record or chart is best left to the initiative of the Surveyor conducting the survey. It is, after all, his responsibility.

I believe that, in the future, in addition to certifying compliance with specified regulations, we shall have to satisfy ourselves as to the quality of materials and workmanship. Standards of workmanship in accommodation vary a great deal throughout the world and we may be required to ensure that the standards envisaged by an owner in his agreed specification are in fact realised. It would be extremely useful if a symposium of papers on materials and workmanship standards, contributed to by as many Outports as possible, could be arranged.

A great deal of thought, based on the most sincere of motives, has gone into the composition of this paper for which the Authors are to be thanked.

## WRITTEN CONTRIBUTION

### Mr. R. RYMILL

As stated in the General Notes on Ventilation on page 11, the method of testing and measuring the air changes per hour is the responsibility of the ventilation or air conditioning engineer, but it is considered that the Surveyor is at a disadvantage if asked to comment on the method to be used or advise during the trial. Therefore, a few notes indicating the instruments generally used and procedure for testing are detailed below for information purposes.

1. **The Reasons for Testing**

It should be remembered that ventilation and air conditioning trials are essential to ensure that the design conditions are being achieved. It is important that each system is balanced correctly before trials are commenced, since the designed air quantities are based on the heat load, etc., when under operational conditions.

The trials procedure entails:—

(a) Provision of performance data for use in checking air quantities from components in the system during the trial, i.e. fan, cooler, heater and punkah louvre curves, etc.

(b) Provision of facilities for measuring and adjusting the air quantities, etc.

(c) A visual examination of the systems.

2. **Instruments**

Instruments are required to measure the following with an acceptable degree of accuracy: —

(a) Air velocity and pressure.

(b) Air temperature and humidity.

There are a variety of instruments available, but it is important to use the type of instrument best suited in each case, to know how it works, and the degree of accuracy which can be expected.

(a) **Air Velocity and Pressure Instruments**

(i) *The Velometer,* as indicated in Fig. 1, is a Air Velocity Meter capable of reading the air speed and pressure within a system. It is a convenient instrument for shipboard use and enables a check to be made on the distribution and performance of the system. Providing the instrument is carefully maintained and serviced at the regular intervals recommended by the manufacturers, the readings obtained should be within approximately $\pm 5$ per cent of the true reading.

Accuracy of velocity and pressure readings obtained can be adversely influenced by the choice of test positions which are subject to turbulence, i.e. immediately following bends, abrupt changes of section of trunking and fittings, etc. Ideally, test positions should be preceded by a straight section of at least six diameters of trunking. To obtain average conditions of pressure and velocity in the duct it is necessary to take a series of readings at different points symmetrically distributed over the cross-section of the duct. The method of using the velometer is indicated in Figs. 2 and 3. From readings taken the average condition of pressure and velocity can be obtained by taking the arithmetic mean. Hence the volume of air in cubic feet per minute is obtained by multiplying the area of cross-section of the trunk (square feet) by the arithmetic mean of the velocity (feet per minute) at that position.

(ii) *The Pitot-static Tube,* as indicated in Fig. 4, consists of two concentric tubes joined and faired at the end and since there are no moving parts it is an ideal instrument for measuring pressure, provided care is exercised in the choice of test position as described previously. When in use the instrument is placed with its mouth facing the air stream which results in it being acted upon by the air velocity and internal duct pressure, whilst the outer tube is acted upon by the internal duct pressure only. Therefore, by connecting the instrument by rubber tubes to a U-tube manometer readings of total head, static duct pressure and velocity head may be obtained. But for more accurate readings of velocity head an inclined manometer is generally used.

An inclined manometer is shown in Fig. 5 and the air flow measured thus: —

The inclined tube D corresponds to one arm of a U-tube, and the large reservoir C corresponds to the other arm. The tubes from the Pitot-static tube are connected to the arms C and D at the openings A and B, the higher pressure tube being connected at A. By making the liquid surface in C very many times larger than the cross-sectional area of the tube D, the variation of height of the liquid surface in C will be extremely small and can therefore be regarded as constant. The pressure difference in the two arms will consequently be given by the reading of the liquid surface in the inclined tube D.

This instrument can be obtained as a combined "Air Flow Test Set". The inclined manometer being mounted on a base which is adjustable horizontally by levelling screws, and the inclined arm being adjustable to $\frac{1}{2}$ in., 1 in., 2 in. and when vertical 10 in. water gauge. Conversion scales are provided to enable direct velocity readings to be read from the inclined tube at the various settings by placing the appropriate scale in the groove alongside the inclined tube, adjusting the zero position accordingly.

The method of taking readings and calculating the volume of air, etc., in the duct, are as described for the velometer.

(iii) *Hot-Wire Anemometer.* This is a battery-operated instrument which can be used for measuring the velocity of air in a duct by measuring the rate of heat loss from a heated body immersed in the air stream; the rate of heat loss being proportional to the velocity of the air impinging on the heated body.

(iv) *Vane Anemometer.* As described on page 11 of the paper, is an instrument more suitable for measuring the velocity in large ducts, such as machinery space ventilation, etc. However, if it can be proved to the Surveyor's satisfaction that readings in smaller ducts can be obtained within the acceptable degree of accuracy, there is no reason why it should not be used for the smaller systems.

(b) **Air Temperature and Humidity**

(i) *Mercury in a Glass Thermometer* should generally be used for recording temperatures during trials and should possess a known degree of accuracy. Alternatively, they should be calibrated against an instrument of known accuracy and allowance made on the temperatures recorded.

(ii) *Alcohol Thermometers* are not generally recommended for trials use as they may be subject to error due to the viscosity of the fluid and separation of the fluid column. If it is absolutely necessary to use one, however, it should be calibrated as in (i) above.

(iii) *Surface Contact Thermometers* are mercury thermometers having a flattened bulb and are designed for recording the temperature of hot flat surfaces.

(iv) *Distance Reading Thermometers* consist of a direct reading dial connected to a length of capillary tubing terminating in a sensing element.

(v) *The Sling Psychrometer* is an instrument for measuring simultaneously the wet and dry bulb temperatures of air, from which the hygrometic properties of the air can be determined by reference to suitable tables or charts. The Psychrometer as indicated in Fig. 6 consists of a pair of thermometers mounted in a frame which is provided with a handle. The bulb of one of the thermometers is covered by muslin which is kept moistened by a wick leading to a water reservoir which should be kept topped up with distilled water.

When readings are required to be taken it should first be verified that the wet bulb is actually wet. The instrument is then whirled for about half a minute and the thermometer readings quickly taken, the wet bulb first. This procedure is repeated until two successive readings of the wet bulb agree, indicating that the minimum temperature

has been achieved. When readings are required at ventilation terminals or inside trunking the instrument should be placed in the air stream and the readings taken in that position.

3. **Inspection**

Before trials are started, the air systems should be inspected to ensure that:—

(a) The system is complete, including the fitting of all recirculation grilles, etc.

(b) Trunking, coolers, heaters, fans, filters and terminals are clean and free from possible debris accumulated during building.

(c) Removable lengths of trunking, cleaning holes and access plates are correctly fitted as required for quick and thorough cleaning of trunks and fittings.

(d) The fan impeller is revolving in the correct direction and that the motor is operating at the correct speed.

(e) All external weathertight covers on supply and exhaust terminals are fully open, recirculation flaps are correctly positioned and that doors, hatches, sidescuttles, etc., are closed appropriate to normal operation of the ship.

(f) Supply and exhaust systems serving the same area are operating. This is particularly important if the system under consideration is drawing air from within the ship, e.g. galleys, bathrooms, etc.

(g) Test positions are selected ready for measurement of air flows and air pressures.

4. **Measuring Air Quantities and Pressure**

(a) When the choice of instruments is made it should be remembered that:—

(i) The Pitot Tube is the most reliable and should be employed generally in preference to other instruments.

(ii) A velometer which has been re-calibrated within the preceding four years, gives satisfactory results and is more convenient to use for velocity readings, particularly on ships afloat. It is essential that velometers are well looked after, and readings taken are to be compared between two instruments at least at the commencement of each trial.

(b) The volume of air circulating is measured in all main and branch trunks by use of the methods and one of the instruments described previously. However, if terminals such as punkah louvres are fitted in trunks, water gauge readings can be taken at each position, and when this is related to the special performance charts produced by the manufacturer the air quantities are obtained.

(c) To check the pressure at which the fan is working, determine the water gauge, by means of a facing tube reading on the suction and discharge side of the fan. The fan total pressure will be given by facing tube reading at outlet minus the facing tube reading at inlet. (Note this is an algebraic difference and normally the facing tube readings at inlet will be negative, i.e. below atmospheric.)
The performance of the fan is checked against the fan characteristic curves. Measured results should correspond within the acceptable tolerance of those indicated on the curve.

(d) A quick method for finding the quantity of air supplied to a compartment served from a system is to take a reading "A" in the trunk where it enters the compartment and another reading "B" where it leaves the compartment, and the subtraction of reading "B" from "A" gives the total quantity of air supplied to the compartment.

5. **Balancing the Air System**

Any procedure the contractor prefers may be used for balancing the system providing the results obtained are satisfactory. Adjustment of the air flow to individual branches should generally be achieved by the use of orifiice plates, i.e. this is a plate inserted in the trunk generally in way of flanges which has a hole cut in the centre to allow the designed quantity of air to pass. The size of the hole is determined by a blank plate being introduced into the air stream until the designed air flow is achieved, then a hole equivalent to the free area is cut in a plate which is then inserted into the trunk. Adjustable baffles of the pivot form are not very convenient as they can be readjusted too easily, resulting in an unbalanced system.

6. **Results**

These can be presented as indicated on page 13 of the paper, but it is usually expanded so that a sheet is made out for each fan system, and the following detailed information included: Fan size, number and manufacturer, type of system, i.e. supply exhaust, etc., fan performance data, i.e. air volume, total water gauge, and if the results are not within the acceptable limit of $\pm 10$ per cent of designed figures the fan r.p.m., volts and amps would be recorded.

With reference to Section 11, Natural Lighting, paragraph 2. It should be noted that in air-conditioned ships, the openings of side scuttles and windows will have considerable effect on the efficiency of the air-conditioning system and a notice should be fitted over them, to the effect that they should be kept closed when air-conditioning is in operation, if they cannot be locked shut.

The above also applies to doors at the boundary of the air-conditioned area and to overcome this self-closing air-tight doors can be fitted inboard of the weathertight doors, etc., so that access is not impaired.

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It would be appreciated if the Authors would comment on the following points:—

1. Ref. Section Deck Coverings: What if any regulations govern the deck coverings in compartments containing high voltage electrical equipment, to prevent an accidental short taking place to the deck, i.e. such as the fitting of rolled linoleum.
2. Ref. General Layout Table (1) General Notes: It is considered that a maximum allowable noise level for accommodation compartments, should be laid down to obviate any misunderstandings to acceptance limits.
3. Ref. "SAFCON" Requirements, page 19. Is there any requirement for the timber used for furniture, fittings and linings, etc., to be fire proofed when used in accommodation spaces, as it is noted that inflammable paints, etc., should not be used.

# AUTHORS' REPLY

To Mr. Beckwith

Mr. Beckwith's remarks and observations are noted with appreciation. He mentions the importance of "feed-back", and suggests that copies of Board of Trade (now the Department of Trade and Industry) correspondence should be forwarded to London Office. It has been realised for some time that the wealth of personal experience gained by individual Surveyors when acting on behalf of the Department of Trade and Industry is not being made of general use to the Society as a whole, due to the fact that correspondence takes place direct between the Surveyor and the D.T.I. and it is hoped that some system can be devised to remedy this deficiency.

The Authors agree that it would be most useful indeed if copies of regulations and/or instructions on the subject of Crew Accommodation in specific cases could be forwarded to Headquarters. As Mr. Beckwith says, the feed-back of information is vital, provided that it is fed back out again in a manner which will actively assist the Outport Surveyor in carrying out his duties. The Authors believe that as the Outport Surveyors' duties become increasingly more onerous and time consuming, then detailed guidance and assistance from London Headquarters will become increasingly more necessary. This, in fact, was the motivation which led to the preparation of this paper.

As Mr. Beckwith says, there is obviously a potential increase in the Society's work in this field. It is interesting to note Article 3(e) of the International Labour Conference Convention (No. 92) concerning Crew Accommodation on board ship (Revised 1949).

> "(The laws or regulations shall) require the competent authority to consult the organisations of ship owners and/or the ship owners and the recognised bona fide trade unions of seafarers in regard to the framing of regulations, and to collaborate so far as practicable with such parties in the administration thereof."

When one looks at the list of Member States of the International Labour Organisations (*see* reply to Mr. Bates), one can indeed see the possibilities of increasing the Society's work in this field.

The Authors are in complete agreement with Mr. Beckwith's remarks on procedures. Those suggested in the paper are for guidance purposes only, and as such will presumably be found more useful by the younger Surveyors. It is not the intention to impose rigid guide lines, indeed it would be foolish to do so. There are several Surveyors with much more Outport experience in this field than either of the Authors, and they will no doubt have developed their own methods. If they consider that these are superior to those suggested, then they will obviously adhere to their own practice. It would be appreciated, however, if the Authors could be advised of any alternative procedures so adopted, to enable information to be collated and fed back to all Surveyors engaged on this type of work.

Mr. Beckwith asks two specific questions and in reply it can be stated that hardwood weather doors are acceptable to all Administrations even insofar as the fire regulations are concerned. It is emphasised that the doors concerned are weather doors. It is also considered opportune at this point to mention glass reinforced fibre glass doors and in this respect it should be stated that reinforced fibre glass compositions can be highly combustible and involve heavy smoke and toxic gases, therefore the use of G.R.P. doors cannot be recommended as a substitute for wood.

Mr. Beckwith then asks as to who decides on the reductions in standards in the requirements for messrooms. The Authors would suggest that a lowering of standards is not the intention and in many cases the more spacious common mess is preferred by the seafarers themselves. "Open plan" homes ashore are extremely popular, so why not at sea? The basic messroom requirements separating deck, engine and catering staff, were formulated from the segregation aspect, and from the old attitude that "oil and salt water don't mix". The effect of these traditional attitudes on the formulation of Crew Accommodation Regulations is dealt with by Mr. E. H. Watts in his excellent paper "Crews' Accommodation in Tramp Ships", read to the Institution of Naval Architects in 1945. Mr. Watts made the point then that such segregation is bad for morale and he actively encouraged the trend towards the breakdown of traditional barrirers by more "Open plan" design of Crew Accommodation. There are many shipowners today who think along the same lines and hence provision in the Regulations to allow common messroom arrangements when required. All arrangements in Table (2) are accepted by the D.T.I. without recourse to the appropriate Seamens' Union, except the single messroom for P.O's and ratings of deck and engine departments and catering staff. This would be subject to the arrangements being acceptable to the Seamens' Union and would be handled by the D.T.I. during the course of a survey carried out on behalf of the latter. The Surveyor would simply comply with the instructions prepared (*see* second paragraph on page 10 of the paper).

In those cases where the Society is carrying out the Crew Accommodation Survey at the request of an owner, a written assurance from the owner would most likely be sought by London Headquarters stating that *any* proposed sharing of messrooms had the full concurrence of all parties involved.

To Mr. Bates

The contribution from Mr. Bates is welcomed and his remarks regarding the siting of Crew Accommodation above the Summer Load Water Line especially in the case of a conversion from the OSD to CSD conditions should be carefully noted.

The information on windows in first-tier deckhouses insofar as the Load Line Rules are concerned is appreciated, as is Mr. Bates' suggestion regarding the lettering of bulkheads in Table 5. As regards the latter, the point is well taken but perhaps might better be left as it is with Mr. Bates' observation serving as due warning. The Authors are grateful to him for pointing out this particular deficiency in the paper.

Due to the shortage of time available when this paper was written it was decided not to include any historical notes. The Authors suspected, however, that this aspect would be raised during the discussion and these suspicions have not been unfounded. The following notes on the background to the present Crew Accommodation Regulations are of necessity very brief but it is hoped that they will suffice in the context of general relative information.

Before any specific Crew Accommodation Regulations were published a form of control was exerted by the Tonnage Regulations, which allowed crew accommodation spaces to be

deducted from the gross tonnage, toilet spaces being treated as exempted spaces. The owner was, therefore, encouraged to provide reasonable facilities for the accommodation of the crew without being penalised by the Tonnage Regulations which did not, however, lay down detailed standards of accommodation.

Mr. E. H. Watts, in his previously mentioned paper, asserted "It can safely be said that until 1936 very little interest was taken in improving crews' accommodation by shipowners, naval architects, the Board of Trade, or even those who used it. The shipowner left the shipbuilder to design accommodation in accordance with the minimum specification sponsored by the Board of Trade in 1923, and reissued and reprinted in 1929". Mr. Watts was, of course, referring to British ships, but the same, generally speaking, could be said for most of the maritime nations at that time.

The breakthrough, relating to the provision of minimum requirements for Crew Accommodation, was effected in 1946 at Seattle through the medium of the International Labour Organisation (I.L.O.). This took the form of Convention 75 "Accommodation of Crews". These requirements were revised by Convention 92 "Accommodation of Crews" (Revised), in Geneva, 1949.

To quote from a published pamphlet, the concerns of the I.L.O. are "improved working conditions, higher living standards and greater opportunity for the world's working people". One of the many activities of the I.L.O. is the adoption of International labour standards to serve as *guidelines* for national action to implement such policies.

The I.L.O. was formed in 1919 with a membership of 45 countries and by 1969 this had grown to 121 countries as indicated in the following list published by the I.L.O. in August, 1969.

As previously stated the first Convention on Crew Accommodation in ships was held at Seattle in 1946 (Convention 75) and this was ratified by only five countries. The Rules formulated at this Convention were then revised at Convention 92 held at Geneva in 1949. Convention 92 was ratified by 20 countries, as marked on the list of Member States.

Four of the Convention 75 signatories were among those which ratified Convention 92 thus abrogating their previous ratification of Convention 75. Bulgaria, however, has not ratified Convention 92 but did ratify Convention 75. These Conventions were intended to provide a guideline to the signatories thereof in formulating their own National Rules. It will be seen from the list that the United Kingdom was one of the signatories of Convention 92 and on 2nd July, 1953, the Merchant Shipping (Crew Accommodation) Regulations were laid before Parliament and came into operation for U.K. registered ships on 1st January, 1954. As explained in the paper, these Regulations are based on Convention 92 of the I.L.O. As Convention 92 was only meant to serve as a guideline, however, the British Regulations are obviously far more detailed.

It is understood that the following countries have Statutory Regulations of their own in compliance with or in excess of Convention 92 (although not all the following have ratified Convention 92).

| | | |
|---|---|---|
| Argentina | India | Norway |
| Brazil | Israel | Peru |
| Canada | Ivory Coast | Sweden |
| Denmark | Malaysia | Switzerland |
| Finland | Mexico | United Arab Republic |
| France | Netherlands | United States |
| Fed. Rep. of Germany | New Zealand | U.S.S.R. |
| Hong Kong | Nigeria | |

It is understood that the following countries have Statutory Regulations at present under revision:—

| | | |
|---|---|---|
| Belgium | Japan | Poland |
| Italy | Mexico | Spain |

It will be noted that the following signatories of Convention 92 are not included in the above lists and the Authors have no knowledge of any Statutory Crew Accommodation Regulations prescribed by these Authorities.

| | | |
|---|---|---|
| Algeria | Ghana | Ukranian S.S.R. |
| China | Ireland | U.S.S.R. |
| Costa Rica | Poland | Yugoslavia |
| Cuba | Portugal | |

| | | | | |
|---|---|---|---|---|
| Afghanistan | *Costa Rica | Iran | Mongolia | Switzerland |
| *Algeria | *Cuba | Iraq | Morocco | Syrian Arab Republic |
| Argentina | Cyprus | *Ireland | Nepal | Tanzania |
| Australia | Czechoslovakia | Israel | *Netherlands | Thailand |
| Austria | Dahomey | Italy | New Zealand | Togo |
| Barbados | *Denmark | Ivory Coast | Nicaragua | Trinidad & Tobago |
| *Belgium | Dominican Republic | Jamaica | Niger Republic | Tunisia |
| Bolivia | Ecuador | Japan | Nigeria | Turkey |
| *Brazil | El Salvador | Jordan | *Norway | Uganda |
| †Bulgaria | Ethiopia | Kenya | Pakistan | *Ukranian S.S.R. |
| Burma | *Finland | Kuwait | Panama | United Arab Republic |
| Burundi | *France | Laos | Paraguay | *United Kingdom |
| Byelorussian S.S.R. | Gabon Republic | Lebanon | Peru | United States of America |
| Cambodia | Fed. Rep. of Germany | Lesotho | Philippines | *U.S.S.R. |
| Cameroon | *Ghana | Liberia | *Poland | Upper Volta |
| Canada | Greece | Libya | *Portugal | Uruguay |
| Central African Republic | Guatemala | Luxembourg | Rumania | Venezuela |
| Ceylon | Guinea | Malagasy Republic | Rwanda | Viet-Nam |
| Chad | Guyana | Malawi | Senegal | Yemen |
| Chile | Haiti | Malaysia | Sierra Leone | Southern Yemen |
| *China | Honduras | Republic of Mali | Singapore | *Yugoslavia |
| Colombia | Hungary | Malta | Somali Republic | Zambia |
| Congo (Brazzaville) | Iceland | Mauritania | Spain | |
| Congo (Kinshasa) | India | Mauritius | Sudan | |
| | Indonesia | Mexico | *Sweden | |

† Ratification of Convention 75 (Accommodation of Crews). (Finland, France, Norway and Sweden also ratified Convention 75, but abrogated same by subsequent ratification of Convention 92.)

* Ratification of Convention 92 (Accommodation of Crews (Revised)).

The Society has carried out isolated Surveys of Crew Accommodation at the request of the Brazilian and Israeli Governments but all other such surveys have been as described under Survey Procedure on page 1 of the paper. The Society was advised in the case of Brazil that the Brazilian Regulations were the same as Convention 92, without addition.

The Israeli Requirements were found to be exactly the same as the British (U.K.) Requirements. It will be noted that Israel has not ratified the I.L.O. Convention 92.

It will be apparent that only on very rare occasions has the Society been requested to carry out a Survey of Crew Accommodation other than as described in the paper, however, as stated in the reply to Mr. Beckwith the Authors believe that there is a great potential in this field. It is felt that the Society might in the future offer its services in a consultative capacity, or as a competent authority, to any country interested in the development and/or implementation of crew accommodation regulations. If this were to materialise then the feed-back system as described in the reply to Mr. Beckwith would no doubt be of great assistance.

There have been two I.L.O. Conventions on Crew Accommodation since 1949, namely Convention 126 at Geneva in 1966, "Accommodation of Crews (Fishermen)" and Convention 133 at Geneva in 1970 "Accommodation of Crews (Supplementary Provisions)". Convention 126 has not been mentioned in the paper as the Society has been requested on only one occasion to carry out the Survey of Crew Accommodation on a fishing vessel. The requirements of Convention 126 are, however, generally similar to the requirements of Convention 92. As Convention 133 was only held last year, its contents were not available at the time of writing, but as the paper, in any case, deals only with British Regulations it is not thought that any major effect will be felt insofar as the Society is concerned.

To Mr. Sneddon

Mr. Sneddon's opening remarks are very gratifying.

As he points out, Rule (2) of the British Crew Accommodation Regulations applies to every U.K. registered ship which is not a fishing *boat*. It is interesting to note, however, that Article 1(3)(c) of the International Labour Conference Convention (No. 92) states that the Convention does not apply to *vessels* engaged in fishing or in whaling or in similar pursuits. For a legal definition of a fishing boat, Temperley's Merchant Shipping Acts has been consulted. The definition therein is as follows: "The expression 'fishing boat' means a vessel of whatever size, and in whatever way propelled, which is for the time being employed in sea fishing or in the sea-fishing service, but save as otherwise expressly provided, that expression shall not include a vessel used for catching fish otherwise than for profit". There appears to be no legal difference therefore between a fishing boat and a fishing vessel. Mr. Sneddon makes a valid point when he states that some fishing vessels may be at sea 60 days or more. Regulations for fishing vessels were, in fact, formulated by the I.L.O. during its Fifteenth Session at Genoa in June, 1966, namely Convention 126, "Convention concerning accommodation on board Fishing Vessels". The United Kingdom have not ratified this Convention and the views of the Department of Trade and Industry in the matter are not known. The I.M.C.O. Sub-Committee on Safety of Fishing Vessels has also considered general standards for Crew Accommodation.

Mr. Sneddon raises a critical point about the requirement for ready means of escape to the embarkation deck. It is the Authors' opinion that if such escape arrangements are acceptable from the fire viewpoint, then they would be acceptable in any contingency.

Comments on the fire aspects of deck coverings, insulation and paints are of great interest and will be carefully noted by all Surveyors, as these aspects cover all ships building to class, and not simply ships on which a Crew Accommodation Survey is being carried out.

To Mr. Coggon

It is very pleasing to hear Mr. Coggon say that the paper would have been of assistance during the particular survey described by him. It is sincerely hoped that it will be of assistance to many more of our colleagues.

Mr. Coggon's comments on the background to Merchant Shipping Notice No. M.592 (referred to in Section 10 of the paper on page 17) are of great interest. It is our understanding that the Society would not accept polyurethane or polystyrene in crew accommodation living spaces. A condition of acceptance in refrigerated storerooms is that such spaces be sited as remotely as possible from sleeping accommodation and places of high fire risk.

The prohibition of bolted couplings in sanitary pipes in provision stores by the United States Coast Guard is good sound common sense. The Authors have no knowledge of any similar requirement being specifically written into any Rules, but would suggest that "good shipbuilding practice" would support the U.S.C.G. view.

Mr. Coggon's criticism of the guidelines suggested for the penetration of Type "A" bulkheads is valid. The relevant sentence should read as follows: "For cables a fire resistant gland is necessary".

The question regarding tonnage and crew accommodation is welcomed as there appears to be some general misunderstanding as to the relationship between the two subjects. The simple answer to Mr. Coggon's query is that when the Society issues a Tonnage Certificate to a Liberian ship, or indeed to any ship, a Survey of Crew Accommodation is not carried out, unless specifically requested. As stated in the reply to Mr. Bates, requests to carry out Surveys of Crew Accommodation on behalf of Governments have been very rare, and the normal procedures are as described on page 1 of the paper.

It is the Authors' opinion, however, that when Tonnage Admeasurement is carried out on a ship registered in a country which has Statutory Crew Accommodation Regulations, then for crew spaces to qualify for deduction from gross tonnage they should comply with the Crew Accommodation of the Government concerned. In other words a full Survey of Crew Accommodation should really be carried out, but this would require authorisation from each particular Government.

In framing his question, Mr. Coggon probably had the procedure for U.K. registered ships in mind whereby the Tonnage Admeasurement is carried out in conjunction with the Survey of Crew Accommodation. The Society's involvement in these surveys is only that they are carried out by their Surveyors specially appointed by the Department of Trade and Industry as described in the paper. The Surveyor thus has full Government authorisation in these cases and is in fact a D.T.I. Surveyor responsible direct to the D.T.I.

Mr. Coggon specifically mentions Liberian ships, and in this respect it should be noted that Liberia does not have Stautory Crew Accommodation Regulations. Liberian law, however, requires the the U.S.A. Tonnage Regulations be applied to Liberian Registered ships, and the definition of a deductible

crew space contained therein is as follows: ". . . every place appropriated to the crew of the vessel shall have a space of not less than 120 cubic feet and not less than 16 square feet, measured on the floor of the deck of that place, for each seaman or apprentice lodged therein, and each seaman shall have a separate berth and not more than one berth shall be placed one above the other; such place or lodging shall be securely constructed, properly lighted, drained, heated, and ventilated, properly protected from weather and sea, and, as far as practicable, properly shut off and protected from the effluvium of cargo, or bilge water. And every such crew space shall be kept free from goods or stores not being the personal property of the crew occupying said place in use during the voyage".

". . . in addition . . . on all merchant ships which in the ordinary course of their trade make voyages of more than three days duration between ports, and which carry a crew of 12 or more seamen, there shall be constructed a compartment, suitably separated from other spaces, for hospital purposes, and such compartment shall have at least one bunk for every 12 seamen, constituting her crew provided that not more than six bunks shall be required in any case."

The above requirements are obviously very general and only a cursory examination is necessary to ascertain compliance. The Society's Tonnage Admeasurement Sheet T2 "Surveyor's Report on Crew Space Accommodation" provides for the inclusion of information necessary to satisfy these general requirements. Reference should be made to the reply to Mr. McCulloch in this respect.

To Mr. Choudhury

Mr. Choudhury's remarks on the possible variation of crew accommodation standards are very interesting. International Maritime Conventions affecting ship design have been mainly concerned in the past with safety, and the furtherance of crew accommodation standards has been conducted through the medium of the I.L.O. There are signs, however, that the question of crew accommodation is becoming more widely recognised by the various Government Authorities concerned. At this moment in time, however, the Society can only, quite naturally, be expected to carry out a Crew Accommodation Survey in accordance with existing Regulations. As stated in the paper, when I.L.O. Regulations are to be complied with, the Society's practise is to use the British Regulations as guidance. Mr. Choudhury would appear to disagree with this, but at the moment no other course of action would appear possible bearing in mind the necessity for consistency of survey requirements.

Mr. Choudhury's remarks on the positioning of crew accommodation are valid. The present regulations state that crew accommodation is to be situated at either amidships or aft. This particular regulation, however, is a legacy of bygone days and was originally intended to negate the practise of housing seamen in the forecastle. In those days, of course, this forecastle accommodation consisted of sleeping berths only, without washing facilities and with only very primitive sanitary arrangements. There were no messrooms or food warming facilities and the food had to be carried forward from the amidships galley. In this day and age it is not inconceivable that comfortable accommodation could be provided forward with all the necessary amenities *in situ*. If this could be done satisfactorily, the Authors see no reason why such a position forward of amidships could not be accepted. If such accommodation were proposed below the bulkhead deck it should be positioned abaft the collision bulkhead.

Regarding the layout of the messrooms, reference should be made to the reply to Mr. Beckwith. The main reason for the original rule separation of messrooms (apart from officers and crew) sprang from the "oil and water don't mix" attitude. The tendency today is more towards the single messrooms concept subject to the agreement of the seafarers concerned.

Mr. Choudhury's observations on standardisation of furniture is an interesting one from the cost reduction aspect, but may not necessarily improve the standard of crew accommodation. Sameness of furniture in all ships could become boring for the seamen concerned. Minimum standards only should be set, and the owner then left to provide whatever extras he feels necessary.

The Authors wish to thank Mr. Choudhury for his thought-provoking contribution.

To Mr. McCulloch

Mr. McCulloch's candid comments provide a valuable contribution to this discussion. The Authors, however, would dispute his allegation that a limited view of the subject has been taken in this paper, the main object being to guide the Surveyor through the Crew Accommodation Regulations omitting reference to background clutter and frills.

Mr. McCulloch states that the Society has been involved for many years in the Survey of British and *non-British* ships, as an integral part of Tonnage Admeasurement. Whilst this statement is valid for British ships and is fully covered in the paper under "Survey Procedure (b)", it is not so for non-British ships. As explained in the reply to Mr. Coggon, in the latter cases a full Survey of Crew Accommodation is not automatically carried out with each Tonnage Admeasurement. Where the Society is not specifically requested to carry out a Survey of Crew Accommodation, only a very cursory examination is required to ascertain suitability for deduction from gross tonnage as an accommodation space. In this respect, reference should be made to the contribution by Mr. W. H. Marsden to the Staff Association paper "Tonnage" by Messrs. R. Gray and L. Beckwith (Sessions 1958–59, Paper No. 2). Mr. Marsden is quite correct in his statement at that time that the Survey of Crew Accommodation is carried out at owner's request, as amplified by "Survey Procedure (a)" in the present paper.

The marking of individual spaces as "Certified to accommodate 1 seaman", etc., is not covered in this paper as such marking is in relation to Tonnage Admeasurement. Such marking is, in fact, fully described in the aforementioned Staff Association Paper "Tonnage" by Messrs. R. Gray and L. Beckwith (page 13). Mr. McCulloch's query as regards the interpretation of Regulation 15(3) of the Merchant Shipping (Crew Accommodation) Regulations 1953, is also dealt with on page 13 of this same Tonnage Paper.

It is hoped that the Crew Accommodation-Tonnage link up has been fully covered in the reply to Mr. Coggon. The Society's forms T1 and T2 are still in use for the computation of tonnage but in general are not now normally completed by the Surveyors where they refer to the lighting and ventilation, etc., of crew spaces. If the Surveyor is satisfied that the crew accommodation reasonably complies with normal standards, and is used solely for the accommodation of the crew, he may certify as such and deduct the space from the gross tonnage. It is repeated that only a cursory examination is required for this.

The Society is indeed authorised to report upon accommodation in Swedish flag ships as per Circular 2131. In such

cases, however, as explained in that Circular, the Swedish Government or the local Consul will provide the necessary forms and particulars of the Survey requirements.

Mr. McCulloch also suggests that the survey of crew accommodation has been carried out on numerous occasions in connection with Specification Service duties. This is perfectly correct as far as it goes. However, when the Society is requested to examine a Specification, the crew accommodation is not necessarily required to comply with any national regulations, and in the large majority of cases only compliance with owners' standards is specified. When the owner declares that the crew accommodation *is* to comply with specific regulations, then specification details are examined accordingly. If the owner also requires a document on completion stating compliance, then the first duty of the Surveyor concerned should be to ensure for the owner that this document is produced; *not necessarily by the Society*. The Government concerned in such cases *may* carry out all the required Statutory Surveys including a Crew Accommodation Survey, with the Society being responsible only to the owner as regards compliance with the specification.

Only when requested by the owner as per "Survey Procedure (a)" does the Society normally carry out a full Survey of Crew Accommodation in accordance with Statutory or I.L.O. Regulations, The Authors are, however, grateful to Mr. McCulloch for raising the question of Specification Services as it is hoped that the paper may prove to be of some guidance and assistance in performing such a service.

Mr. McCulloch states that a *raison d'être* for crew accommodation rules, would be useful, and proceeds to elaborate most competently on such reasons. The Authors' reply to Mr. Bates also covers some of this ground.

Regarding the Society's approach to a situation as laid down in Regulation 35(e) and (f) of the British Regulations, the Authors would suggest the normal line taken by the Society in the carrying out of Statutory Surveys. In all Statutory Surveys the Society is invested with the authority of the Government concerned merely to carry out the survey in accordance with the Rules as recognised by that Government. In the event of non-compliance the Society would be expected to advise the particular Maritime Authority accordingly. The Authority concerned would then take whatever legal action they considered necessary. Any request for survey or inspection by any organisation other than the Maritime Authority would similarly be referred to the Authority concerned and instructions awaited, unless prior arrangements had been made to cover such an eventuality.

The Authors concur with Mr. McCulloch's penultimate paragraph and such a symposium as suggested by him would be most useful.

The Authors would once again thank Mr. McCulloch for bringing up such controversial issues. We believe that controversy and constructive criticism such as he has made is essential in stimulating a fruitful and lively exchange of views.

To Mr. Rymill

Mr. Rymill obviously had considerable experience in the testing of air conditioning systems during his time with the Admiralty and his contribution is greatly appreciated. He has spent a great deal of his own time setting down information which should be of benefit to his colleagues in general and to the Authors in particular and this addition to the fundamental notes given in the paper must greatly enhance its value.

In reply to the questions posed by Mr. Rymill, the Authors would reply as follows: —

1. There are no known Crew Accommodation Regulations governing deck coverings in compartments containing high voltage electrical equipment. It should be noted, however, that the 1960 Safety of Life at Sea Convention and the British Cargo Ship Construction and Survey (S.A.F.C.O.N.) Rules 1965 contain regulations governing precautions against shock, fire and other hazards of electrical origin. Compliance with these regulations (which are also covered fully by Chapter M of the Society's Rules) will provide all the protection necessary for the safety of the crew. Special deck coverings are not specifically requested, adequate protection being sought by the high standards required for electric circuits and cable insulation.
2. There is no statutory requirement known to the Authors fixing a maximum allowable noise level in crew accommodation, much being left to the Surveyor on the spot in this respect. Nevertheless, the subject of noise level is very much to the fore in the technical forum of today and Mr. Rymill makes a very valid point.
3. There are no known requirements in the S.A.F.C.O.N. Rules as regards timber in crew accommodation. It should be noted that the use of non-inflammable paints, etc., does not make the woodwork flameproof.

## GENERAL

The Authors would take this opportunity of adding one point overlooked during the preparation of the paper, this being that information regarding the use of plastic pipes in cold fresh water piping arrangements can be found in Chapter R(B) of the Society's Rules—"Provisional Rules for Plastic Pipes". Note should also be taken of Chapter R(D) of the Society's Rules—"Guidance Notes on Metal Pipes for Water Services".

An addendum of corrections and additions has been published, but to save reprinting this addendum it is thought wise to quote it at this time.

Page 7 General Layout Table (2).
Persons per Room: Chief Radio Officer or only Radio Officer should be included under officers having a single room to themselves.

Page 8 General Layout Table (3).
The reference in the top right hand box should read. "SEE ALSO GENERAL LAYOUT TABLE (5)".

Page 11 In the right hand column in the line above the word "quality" should read "quantity".

Page 13 In the fourth column of the table, the heading "Vol" should read "Vel". (Meaning velocity.)

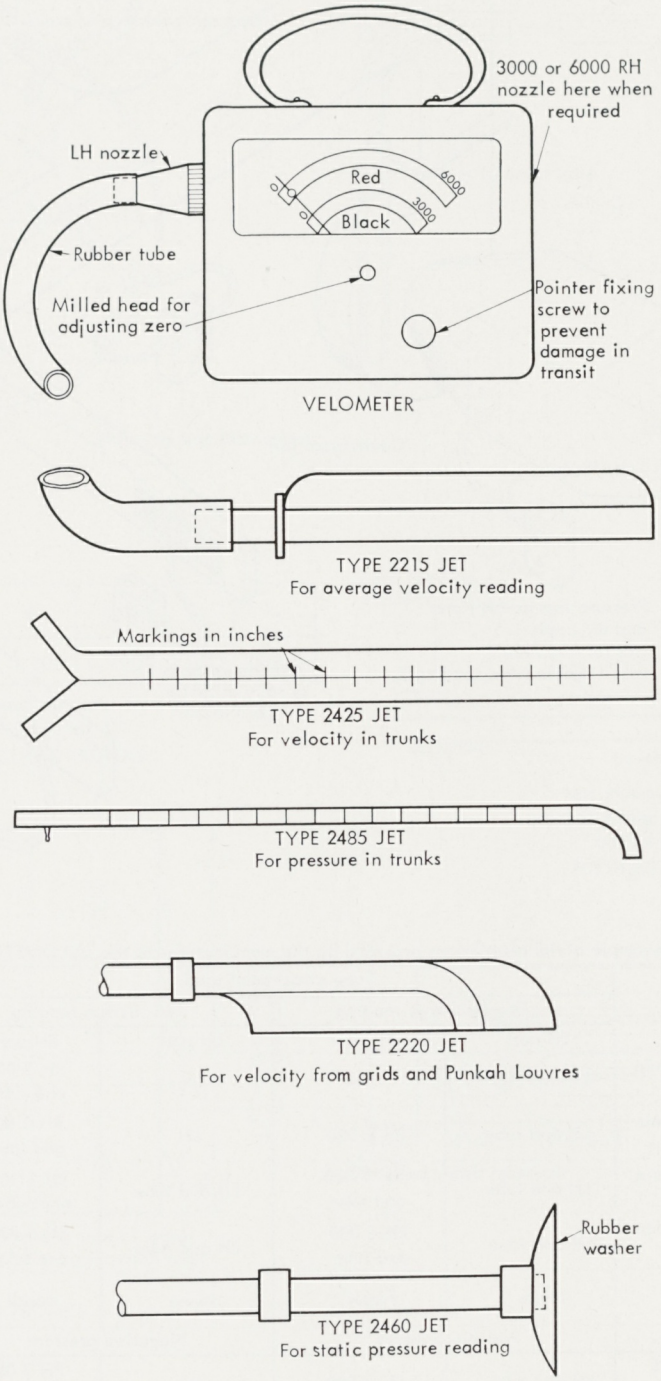
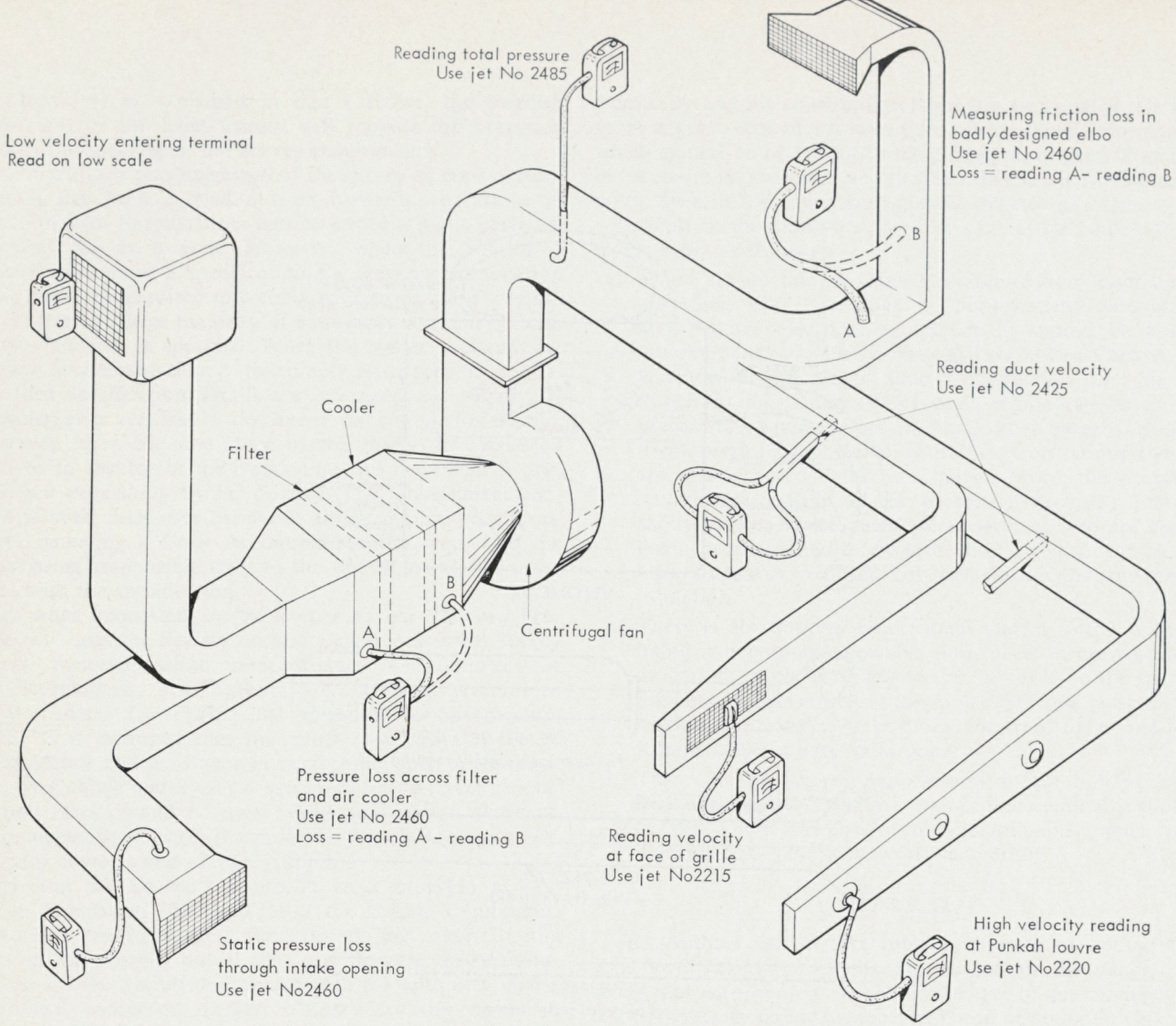



FIG. 1

Velometer—details.

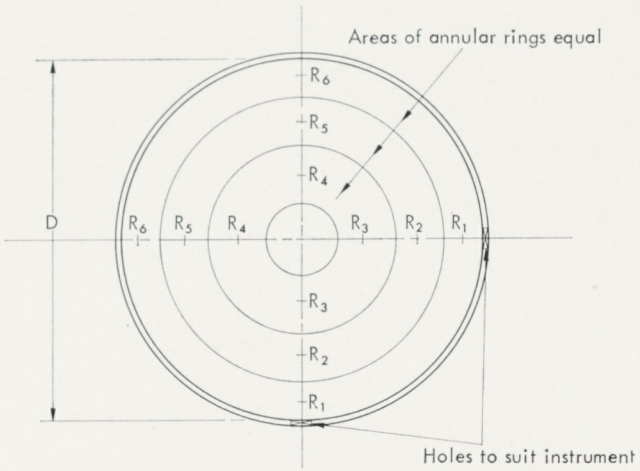



Typical example of the instructions provided by the manufacturer of the VELOMETER

| Jet | Range | Tube attachment used | | | | No of rubber tubes in use |
|---|---|---|---|---|---|---|
| | | Fan discharge reading | | Fan suction reading | | |
| | | LH port | RH port | LH port | RH port | |
| 2220 or 2215 | 0 - 3 000ft/min scale black | LH and tube | None | None | RH 3 000 and tube | 1 |
| 2220 or 2215 | 0 - 6 000ft/min scale-red | LH and tube | RH 6 000 | LH | RH 6 000 and tube | 1 |
| 2425 | 0 - 3 000ft/min scale-black | LH and tube | RH 3 000 and tube | LH and tube | RH 3 000 and tube | 2 |
| 2425 | 0 - 6 000ft/min scale-red | LH and tube | RH 6 000 and tube | LH and tube | RH 6 000 and tube | 2 |
| No jet | 0 -300ft/min scale-black | None | None | None | None | None |
| | | Positive pressure | | Negative pressure | | |
| 2460 | 0 -6in WG scale-black | LH and tube | RH 3 000 | LH | RH 3 000 and tube | 1 |
| 2485 | 0 - 6in WG | LH and tube | RH 3 000 | LH | RH 3 000 and tube | 1 |

FIG. 2

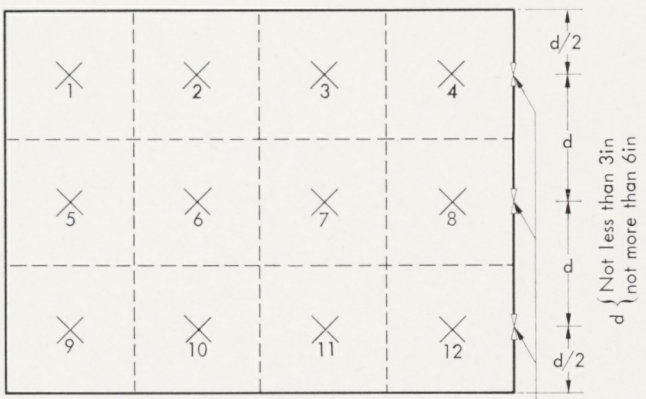
The use of the Velometer with various standard jets to test air duct system.




| No of equal areas | No of readings | $R_1$ | $R_2$ | $R_3$ | $R_4$ | $R_5$ | $R_6$ |
|---|---|---|---|---|---|---|---|
| 3 | 12 | 0,04D | 0,15D | 0,30D | 0,70D | 0,85D | 0,96D |

$R_1$, $R_2$ etc. distance of test points on each diameter from inside edge of trunk in terms of the inside diameter of the trunk D

TRAVERSE FOR CIRCULAR TRUNKS




TRAVERSE FOR RECTANGULAR TRUNKS

FIG. 3

Method of taking readings by pitot tube or velometer.

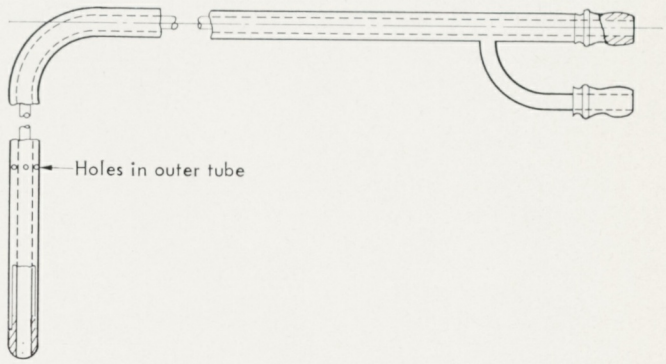



FIG. 4

Pitot—static tube.

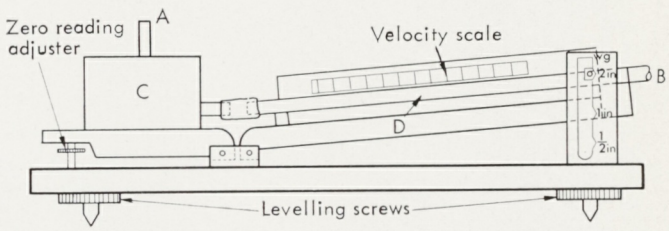



FIG. 5

Inclined manometer.

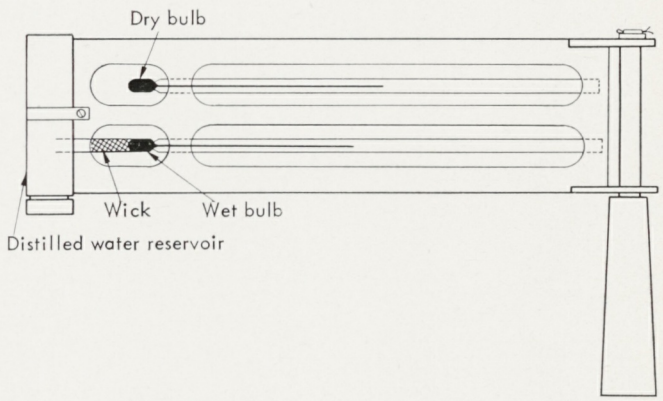



FIG. 6

Sling psychrometer.

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# APPLICATION OF ON LINE PROCESS COMPUTERS IN SHIPS

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# APPLICATION OF ON LINE PROCESS COMPUTERS IN SHIPS

By J. HANCOCK


## SYNOPSIS

The application of computers to ships is discussed, and the functions of on line process computers are examined with particular application to an individual experimental system now operating on board a large tanker built in Sweden.

Examination of the computer is restricted to an explanation of the basic arrangement and function of the hardware to carry out the process operations.

The environmental problems associated with the installation of this type of equipment are examined and the advantages which may be offered by the use of on line process computers are discussed.


## INTRODUCTION

The role of the computer at sea has developed in distinct stages of application. The following remarks regarding the use of computers for on line process control can be described as the movement into stage two application.

Stage one application computers have been operating at sea for a number of years. Their application being in a supervisory and advisory role, to reduce certain aspects of the work load on board. Typical applications are as aids to scientific investigation in research vessels, or for administration functions in commercial ships, such as processing of port papers, i.e. crew and stores lists and simplification of finance matters on board.

Following the lead of the process industries ashore, where direct on line process control has been successfully operating for some years, the marine industry has moved into the second stage of computer application with the introduction of a measure of direct digital control of systems. This stage of development will include: —

Direct digital control of machinery functions.

Trend recording and display of variables.

Completely automated cargo loading and discharge.

Calculation of loading data such as displacement, tank capacities and optimum loading plan.

Automatic steering and course prediction.

Navigation aids, incorporating updating of the ship's position, based on course and speed information from the gyrocompass and electronic log. At this stage using conventional instrument measurement, but eventually information via satellite will be available as an aid to weather information and position fixing.

A third stage of application will probably follow, whereby the computer would function more as a controller than as an adviser, while the crew would serve as monitors of the computer system and provide back-up redundancy in emergencies.

A small number of experimental projects studying the use of on line process control are operating at sea or are projected and it is one of these projects fitted in a large Swedish tanker which is being used to illustrate the practical application of the computer as a means of control of functions in ships.

## COMPUTERS IN CONTROL SYSTEM CONCEPTS

In most control installations, variables are monitored by some sort of recording equipment, so that the operator can keep track of current status and process trends and disturbances. The changeover to UMS operation of ships means that complex processes need to be closely monitored by instruments, and continuous measurement and recording of the process variables becomes increasingly necessary for close and economical control. To continuously record process changes a data handling system may be added to a conventional process system. The basic elements of a computerised data acquisition system is illustrated (Fig. 1).

The heart of the data handling system is the digital computer and once inputs are brought onto the computer memory, the data can be verified, computed, formatted and printed out in a variety of ways.

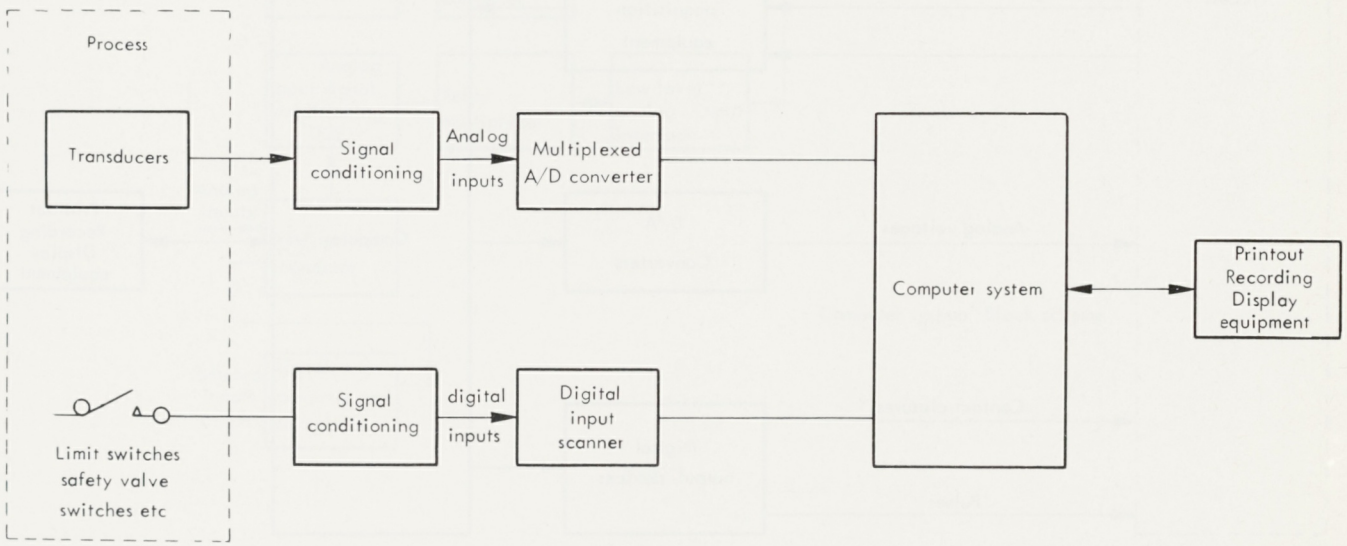



FIG. 1

### Analog Inputs

Process sensors such as thermocouples, potentiometers, pressure transducers, etc., convert physical actions or quantities to proportionally varying electrical signals. These signals must be converted to digital numbers acceptable to a data processer. Conditioning of signals may be required to make the signals acceptable to the converting equipment, for instance, to provide amplification for low level signals, or to transmit signals over long lines. In order to time share the analog/digital converter when many inputs are to be scanned, a form of sequential switching must be incorporated. The multiplexer used for this purpose can be combined with the conversion operation.

### Digital Inputs

In addition to converted analog inputs, the computer can accept digital or contact closure information. Process related on-off signals such as alarms and limit switches, for example, signals generated by limit switches during cargo handling, can then be correlated with the analog data. Direct digital transducers, such as turbine flow meters, interface to digital input channels without intermediate analog/digital conversion. Signal conditioning may again be required to match the signals to the computer logic levels.

In order to achieve better control of the numerous variables in a process, the computer system can be further extended to carry out the process control functions automatically.

The on line control system uses data acquisition input equipment to pick up analog and digital signals from the sensors. The control loop is closed by digital to analog converters and digital output channels which reconvert the outgoing signals, required to actuate the process controllers and actuators. A basic system with data acquisition input equipment and analog and digital control output facility is illustrated in Fig. 2.

## COMPUTER SYSTEM ARRANGEMENT

The general computer system previously discussed, in which the central processer and analog and digital inputs and output control signals are mentioned forms the basis of the computer system chosen for the installation under examination.

The system is a basic industrial modular system which allows for flexibility of design and installation and the use of standard peripherals and is probably typical of the type of installation which will be used at this stage of development, if such comprehensive schemes prove successful.

The block diagram Fig. 3 gives a logical layout of the main units employed and the function of the units is briefly explained.

## COMPUTER

The computer or central processor is a stored program, digital computer, designed for high computation and input/output speed, which performs arithmetic and logical operations required by the instructions of a stored program. The computer also generates the commands necessary to execute input and output operations. It is used for computation in real time and its main characteristics are:—

Parallel mode of operation

18 bit storage word—16 data bits

1 parity bit

1 program protect bit

Primary word store made up in units of 4k words to a present word store of 24k which is expandable to a maximum 32k words.

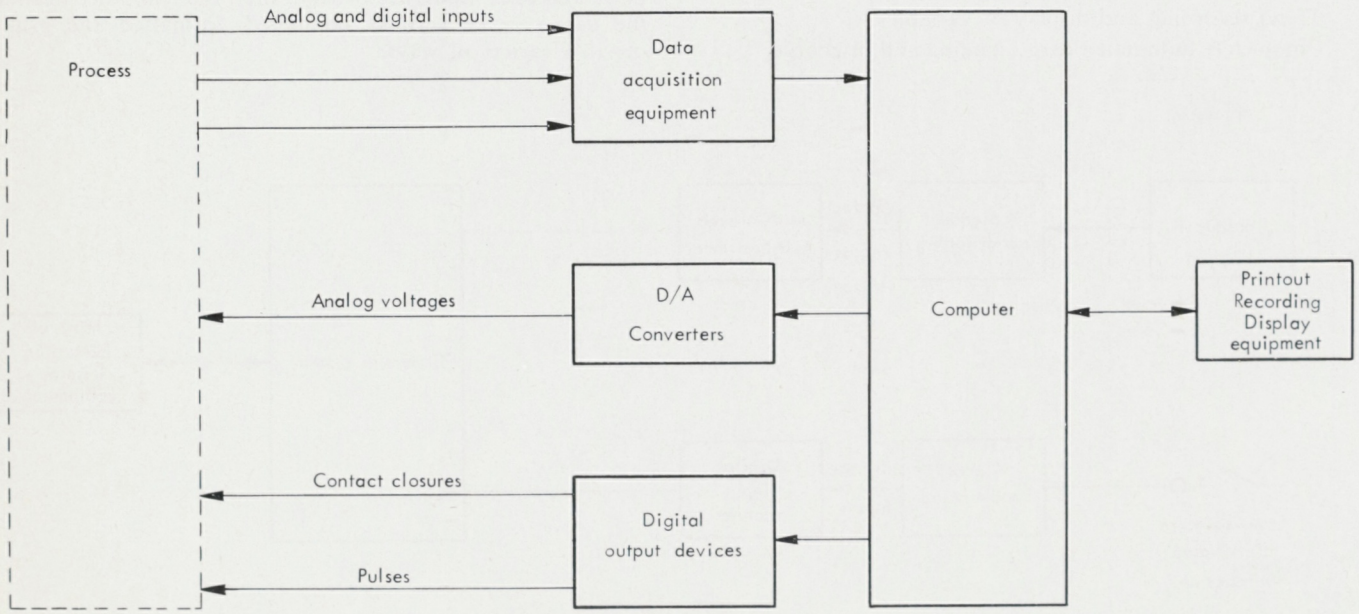
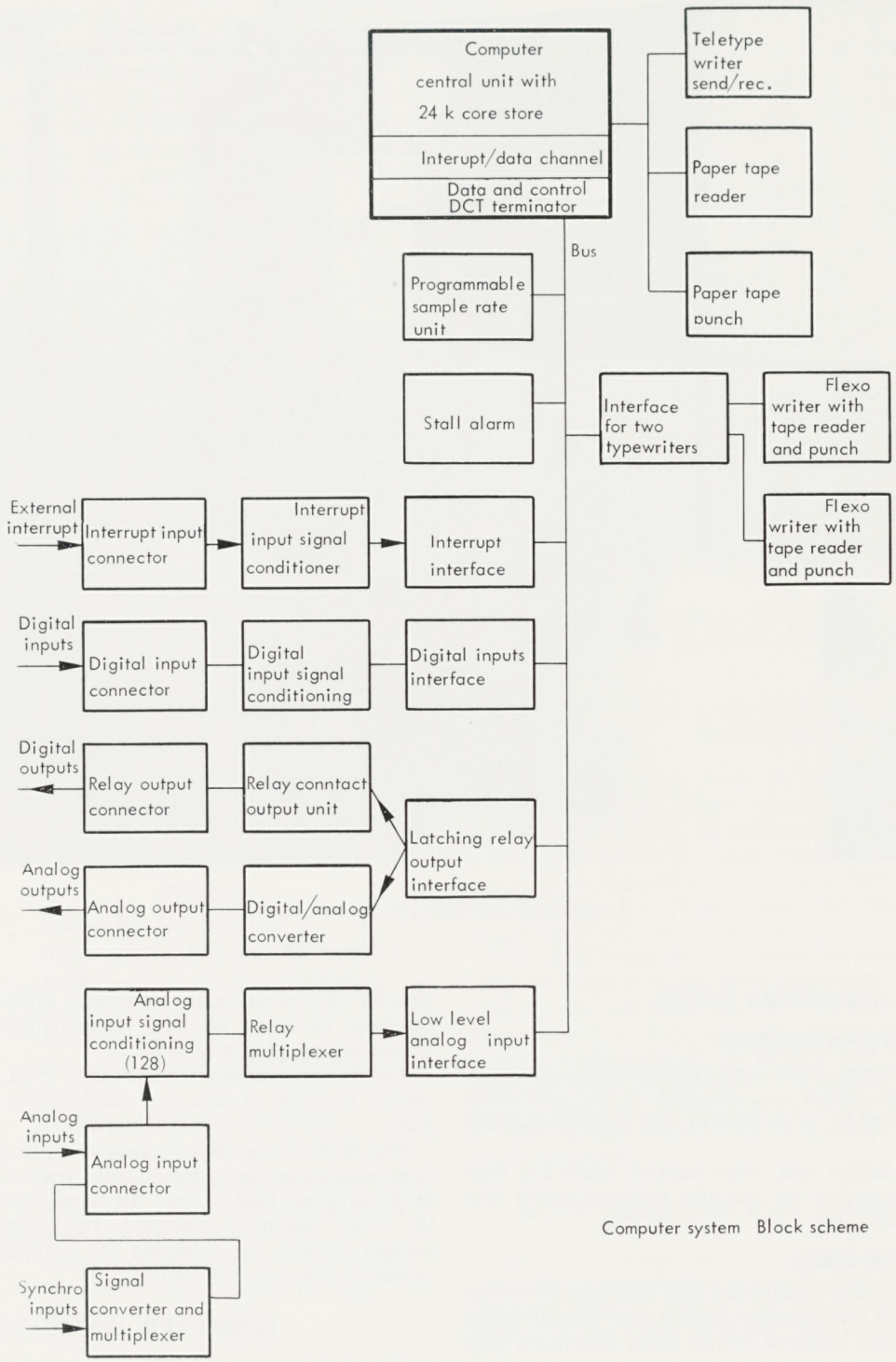
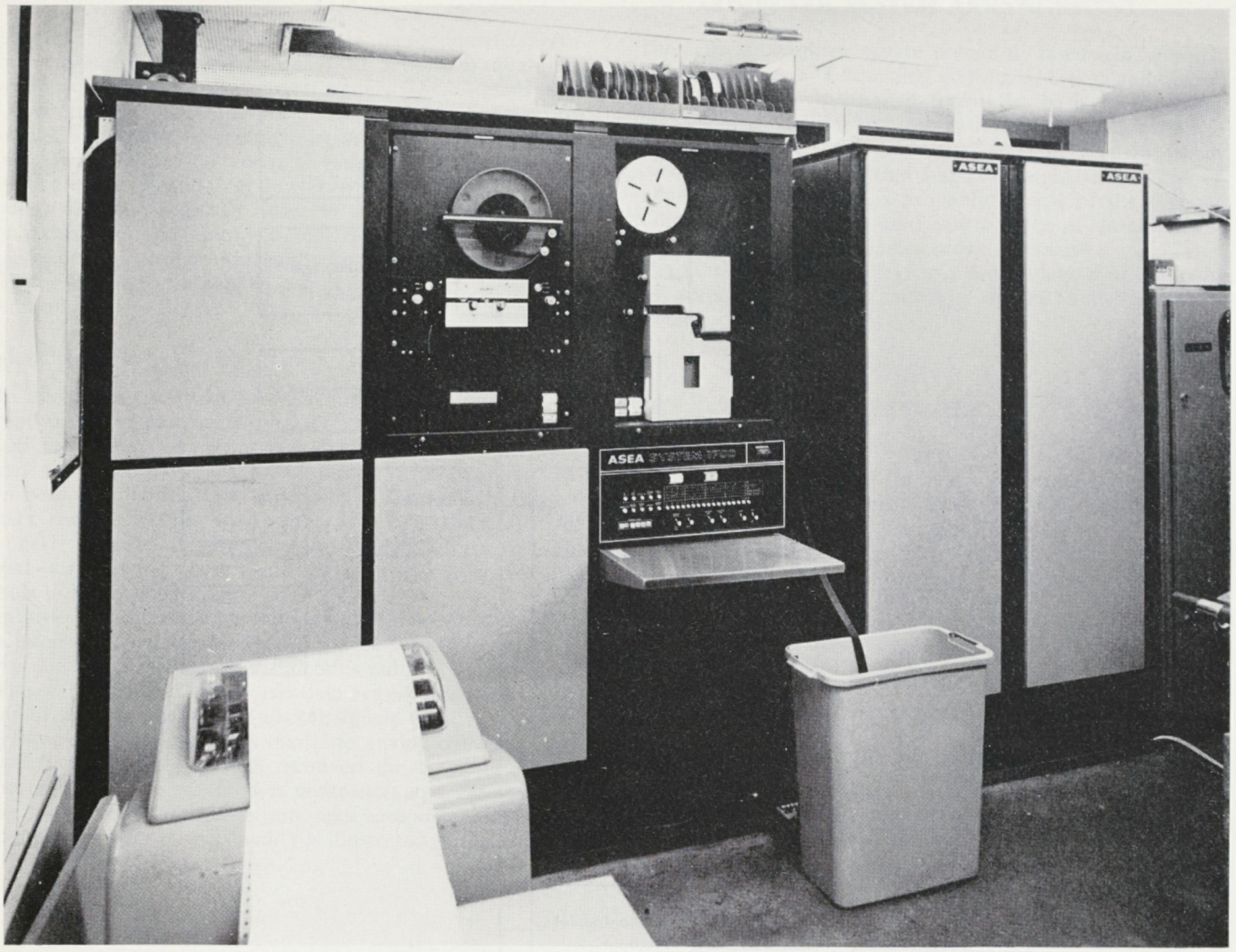



FIG. 2




Computer system Block scheme

FIG. 3




Computer and Teletype typewriter.

## ACCESSORY UNITS

### Operator Communication Peripherals

The paper tape reader, paper tape punch and the automatic send/return teletype writer are installed in the machinery control room adjacent to, or as part of, the computer central installation.

In addition the bridge and cargo control room are each equipped with a typewriter for operator communication with the central processor.

### Input and Output Sub-system

The analog inputs are conditioned and multiplexed before being interfaced with the computer central unit. Digital inputs are conditioned where required before being interfaced with the computer.

The outputs are reconverted where necessary, i.e. the analog outputs are converted to digital signals in order to be available for use as process signals.

The External Interrupt Sub-system is used to determine the priority of various operations in that an interrupt of higher priority can interrupt the computer while it is processing an interrupt of lower priority. Process priorities can be determined during programming.

The Programmable Sample Rate Unit, or Crystal Clock, directs the flow of data and controls the sequence of operations.

The Stall Alarm detects program failures. It requires the computer program to periodically reset a "watchdog" timer. If the program fails to reset the timer within the given period, the "stall" alarm is indicated. The system also produces a contact closure for reverting the computer controlled processes to conventional control.

## COMPUTER APPLICATION

The object of the experimental computer installation is to centralise differential control and supervision systems in order to determine whether closer controls with a higher degree of reliability can be obtained, than is possible with conventional hardware and examine whether economies in expenditure on instrumentation may be possible.

The installation under consideration has been programed to perform the following functions:—

1. Remote control of the main turbine machinery from the bridge, considering signals giving the ship's speed, boiler pressure and other variables.
2. Control of the main boiler, combustion air, fuel oil, feed water flow, and steam temperature.
3. Data handling and alarm scanning of a number of temperatures, pressures and levels will be carried out, together with certain efficiency calculations.
4. Direct digital control of a number of closed loops in the engine room.
5. Steering control in which the computer performs the function of the autopilot.
6. Navigational computations of astral position fixes, great circle navigation and dead reckoning as ordered by the officer on the bridge.
7. Loading and discharging of cargo automatically carried out by a sequencing program which also continuously calculates hull shear forces and bending moments. Cargo handling time will probably be reduced.
8. Strain computation for the hull during cargo handling.

A process control computer carries out its duties in accordance with a set program, which is fed into the computer. The program must contain the type of operation to be carried out and the address of the operands for passing on by instructions to the control unit. The programs must be drafted in a suitably coded program language and presented to the computer, in this case by means of punched paper tape.

Programs have been written for computer control of detailed processes on board. These have in the main been compiled on the basis of design and theoretical knowledge. Changes have been made and are still being made to some of the programs, but the following is a list of the programs which have been compiled, most of which operated successfully, during the first voyage.

| Program Number | Program |
|---|---|
| 05 | Four-hours log print-out |
| 08 | Boiler control (Oil and Air Regulation) |
| 09 | Bridge control of main machinery |
| 12 | Steering prediction |
| 13 | Turbine efficiency<br>Printed out on four-hours log and on demand |
| 17 | Display instrument on panel |
| 19 | Great circle navigation computation |
| 20 | Automatic instrument navigation |
| 22 | Automatic pump control L.P. steam generator feed water |
| 23 | Main cooling water, scoop control |
| 25 | Automatic valve control for the exhaust steam system |
| 28 | Average H.P. developed |

In addition the following closed loops are monitored and controlled by conventional control systems, but the signals can be fed into the computer by a simple change-over-routine, whereby the analog controllers are switched out of the system; all computation being carried out by the computer.

| Loop Number | Control Loop | Address |
|---|---|---|
| 01 | Port boiler water level | 01E9 |
| 02 | Starboard boiler water level | 01EA |
| 03 | Port boiler superheat | 01EB |
| 04 | Starboard boiler superheat | 01EC |
| 05 | L.P. steam generator pressure | 01ED |
| 06 | L.P. steam generator drain level | 01EE |
| 07 | L.P. steam generator feed water | 01EF |
| 08 | Gland steam | 01F0 |
| 09 | Exhaust steam | 01F1 |
| 10 | H.P. drain tank level | 01F2 |
| 12 | Fuel oil viscosity | 0563 |
| 13 | Deaerator spill | 01F5 |
| 22 | Deaerator make up | 0568 |

Obviously some of the control loops are linked with the programs and it should be mentioned that, as part of the Boiler Control Program 08, the control systems for the port and starboard burner oil valves and air registers and the excess steam dump valve are started automatically by the start of program 08.

Starting of program 22—Automatic pump control of the L.P. steam generator feed water—automatically starts control loop 07 which is the L.P. steam generator feed water control, and program 25—Valve control for the exhaust steam system—automatically starts the exhaust steam system control loop 09.

The loading of programs and the starting and stopping of programs is carried out by the operator.

## BOILER CONTROL AND CONTROL OF PROPULSION MACHINERY

Integrated response from the boiler plant to changes in demand from the control station is necessary for efficient control in order to avoid excessive pressure, temperature and level deviations in the steam system. The computer accepts input signals from the control position and the propeller shaft and generates an output signal for the operation of the manœuvring valve at the turbine.

The signal from the command position gives the demand r.p.m. and that from the shaft actual r.p.m. The timed process program for computer control ensures that a large demand r.p.m. does not result in a large steam demand resulting in possible overloading of the turbine and leading to bad propeller efficiency. In the case of a sudden reduction in steam demand the total power demand signal in the system could be negative and steam is led via a dump valve to the atmospheric condenser.

## DATA HANDLING AND ALARM SCANNING

As well as being used for process control functions the computer is programmed to handle process measurements and compare these to provide an alarm facility for off limits excursions from the set point. The computer inputs consist of:—

(1) Analog inputs (including synchro units used for tank level measurement).

(2) Limit signal inputs.

(3) Digital inputs.

Analog inputs: A process input acquisition system sequences the analog inputs via the analog/digital converter.

An input scan sequencer sequences the scan for each point; driver routines read in the data from the analog/digital converter and conversion routines convert the measured values to required units which are stored. Limit compare routines compare the converted values to preset limits and alarm routines assemble the descriptive alarm messages when off limits conditions occur. These are printed out on the printer as alarms and are recorded for the operator.

The scanning time interval can be varied for various parameters.

Limit Signal Inputs: For the limit position signals used for example in the cargo handling system, a routine is used which counts the number of pulses during a fixed time period (initially this was set at 10 secs.)—and converts the signals to engineering units. Alarm is given in the machinery control room and cargo control room for off limits excursions.

Digital Inputs: These can be handled by the digital computer without pre-conditioning.

Alarm and print-out of the measured values are classified in groups depending on whether the parameter to be measured needs to be continuously scanned for alarms or needs only to be printed out at intervals for the information of the operator.

A four-hour log print-out was arranged, program 05, with the operator able to obtain specific information on request. It is possible to rearrange the parameters to be recorded.

Four Hour Log Print Out

LOG REPORT TIME 1600 DATE 0 0 0

| NO | VALUE | UNIT |
|---|---|---|
| 12 | 83.14 | RPM |
| 145 | 15.59 | KNOTS |
| 90 | 2405.20 | KILONM |
| 201 | 0.00 | KW |
| 202 | 0.00 | G/KNM |
| 93 | 2422.00 | KILON |
| 107 | 58.90 | FEET |
| 109 | 61.18 | FEET |
| 103 | 10.38 | M/S |
| 101 | 220.80 | DEGR. |
| 105 | 885.20 | KG/M3 |
| 99 | 0.00 | KW |
| 7 | 59.68 | BAR |
| 55 | 9.48 | BAR |
| 8 | 32.36 | BAR |
| 60 | 11.65 | BAR |
| 59 | 2.89 | BAR |
| 61 | 0.26 | BAR |
| 62 | 497.80 | DEGR.C |
| 63 | 499.00 | DEGR.C |
| 117 | 274.20 | DEGR.C |
| 118 | 272.30 | DEGR.C |
| 119 | 334.60 | DEGR.C |
| 120 | 196.60 | DEGR.C |
| 123 | 157.40 | DEGR.C |
| 124 | 145.20 | DEGR.C |
| 125 | 53.26 | DEGR.C |
| 130 | 29.38 | DEGR.C |
| 131 | 34.72 | DEGR.C |

## SHIP STEERING CONTROL

Ship steering by Computer-Autopilot. The system is programed for two functions, to steer the ship on a given compass course and to present a predicted course for the ship during a forward time cycle of ten ships lengths. The two functions will not be used together as the course prediction is only of value during manual steering.

In order to use the Computer-Autopilot system the watchkeeper checks, through the bridge typewriter, that the computer is reading the correct course. In order to do this a function code is typed out using a four letter code similar to that used in the loop and program starting. If the value varies from the gyrocompass course another function code is used to calibrate the compass. Once the change-over from the conventional autopilot system has been made, the course steered is that fed in at the change-over, any further change in course being fed in by the watchkeeper using the correct function code. Changes in the steering parameters for weather conditions and tide can also be made by the operator.

Navigational Computations can be made by the computer using such data as:—

Fixed Latitude and Longitude.

Tide and wind velocity and direction.

With this information the computer returns a position by dead reckoning.

The computer can also be used to shorten the calculation time with Great Circle Navigation. When the destination latitude and longitude positions are fed into the computer a print-out is obtained on the bridge typewriter of calculated course, distance to destination, time of passage and average speed of the ship. This information can, of course, be used for the start of the program for steering by computer.

## DIRECT DIGITAL CONTROL LOOPS

### Main Boiler Feed Water Control

Main boiler feed water loops 01 and 02 have been arranged to control the main boiler feed water, two identical installations being used one each for port boiler and starboard boiler. Control is arranged that feed water filling is in concert with the steam output, so that the water level never goes outside the set limits.

The method used is a two-element control system involving water level and water mass in the boiler. The control system has two differential pressure transducers, one placed in the dome and arranged so that the output is proportional to the level. When the water level falls an error signal opens the filling valve. The other differential pressure transducer is connected to the top and bottom of the boiler and measures the total water mass. The function of the system is such that with a large demand from the boiler the boiler pressure falls with accompanying "swell" in the water. During the transitionary period, the level in the drum rises and the signal from the transducer is given to close the valve. Since this is in direct contradiction to the direction in which the valve is required to operate (the water filling rate should, in fact, be increasing), the boiler water mass transducer now comes into operation and gives an output signal, indicating that the water mass has been reduced and this influences the valve to the correct position for re-stabilising the water level.

### Superheater Control

Loops 03 and 04 are arranged for superheater control on both the port and starboard boilers. Diagram Fig. 4.

The system is intended to control the steam temperature at a desired value. The temperature of the superheated steam is measured and fed into the computer where it is compared with the desired value. After comparison a signal is returned to the process control, where the proportioning valve is repositioned to eliminate the error value by passing a proportion of the steam over the cooler as the temperature rises or passing more steam through the cooler by-pass for falling temperature.

If the error value is larger than a fixed value, set as an error limit, only the proportional control factor is used to reduce the overshoot and stabilize the process. The integral value will be switched in when the system has settled.

## L.P. STEAM GENERATOR

### Pressure Control

The L.P. steam generator control is provided by loop 05.

Supply of H.P. steam to the steam generator is regulated by means of the steam pressure output from the generator which is required to remain constant.

A pressure transducer measures the L.P. steam pressure and, depending upon the pressure, operates two supply valves. These operate in split range, one valve operating from closed to open in the range 4-12mA and the other in the range 12-20mA.

The pressure signal is again fed to the computer where it is compared with the desired value of steam pressure. The error signal is amplified and conditioned in the computer, and the resultant output signal is fed to the controller for the necessary action to admit or retard the admission of heating steam.

### Drain Level Control

The L.P. steam generator level control is achieved through the loop 06.

The system is arranged so that the drain cooler is always filled. A differential pressure sensor measures the level and, depending on the signal, delivers water to the deaerator via two valves. These work again in split range similar to those in the pressure control system.

The level signal is fed to the computer, and computed in a similar manner to that previously described.

### Generator Feed Water Control

The L.P. steam generator feed water control is provided by computer controlled loop 07.

The water for generation of L.P. steam is pumped from the drain tank through the drain cooler to the steam generator. The pumps are operated through "bang-bang" control of the water level in the generator.

A differential pressure transducer in the generator measures the water level. If the measured signal is under a fixed value—10mA in this case—a small capacity pump starts and operates

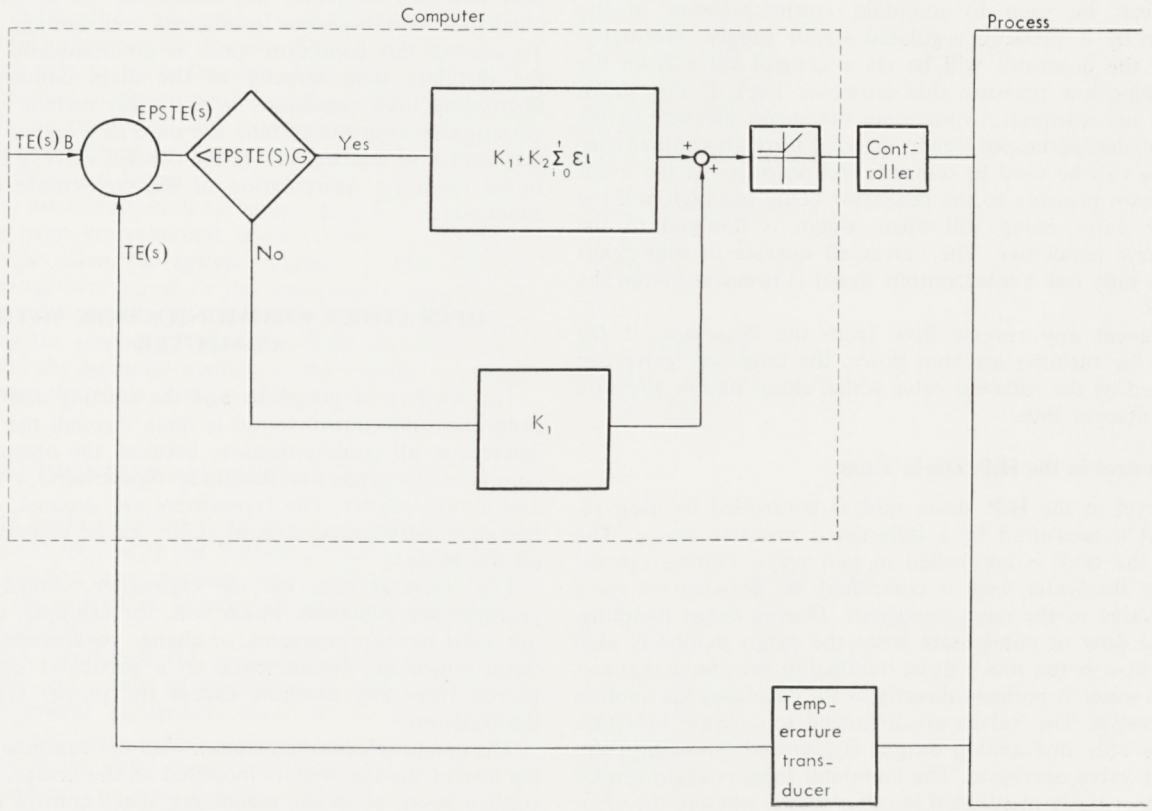



FIG. 4

until the signal is 14mA. If the pump delivery is too small and the level continues to fall, the large pump cuts in at 8mA signal and restores the position, and the small pump stops. When the measured signal reaches the value of 15mA, the large pump cuts out.

However, if the generator water level is raised too quickly at the equivalent of the large pump capacity, the H.P. system cannot deliver sufficient heating steam to cope with this capacity without the generator being cooled. In order to avoid this condition some of the water is tapped off after the large pump and flows back to the drain tank. The recirculated water is controlled through a valve which is closed at low water level in the generator and open with high level.

**Turbine Gland Sealing Steam**

Loop 08 controls the turbine gland sealing steam system during the time the turbine is running.

The sealing steam is supplied from the exhaust steam system. Control of the gland steam is achieved through measuring the pressure in the crossover line between the H.P. and L.P. cylinders. A pressure sensor is situated in the crossover and depending on the signal, controls the regulator valve, which varies the supply of gland steam to the shaft seals.

**Exhaust Steam System**

A constant steam pressure is desirable to give good deaeration and to prevent, for example, cavitation in the feed pump, which is drawing off water from the deaerator. Loop 09 is arranged to control the supply of steam to the deaerator. It is arranged so that exhaust steam, from say an auxiliary turbine can be used to maintain steam pressure in the deaerator by a pressure regulated steam supply. Normally, steam to the deaerator will be via a control valve from the H.P. turbine low pressure side crossover line). If this steam supply is not adequate to maintain the steam pressure in the deaerator, desuperheated steam, directed through another control valve can be used to reinstate the pressure. In the event of the steam pressure to the deaerator being too high and the crossover valve being still open, steam is dumped to the atmospheric condenser. The valves all operate in split range therefore only one analog output signal is necessary from the computer.

To prevent any reverse flow from the deaerator, if for example the turbines are shut down, the crossover valve can be blocked by the solenoid valve which closes on low pressure in the crossover line.

**Level Control in the H.P. Drain Tank**

The level in the H.P. drain tank is controlled by loop 10. The level is measured by a differential pressure sensor. The level in the tank is controlled in two ways. During normal operation the water level is controlled, by drawing off via a control valve to the main condenser. During cargo handling, when the flow of condensate from the cargo pumps is such that the flow is too much to be handled in the above manner, the drain water is pumped directly to the deaerator via another control valve. The valves are arranged to operate in series, therefore only one analog output is required from the computer for valve operation. The computer logic is again similar to that previously mentioned in other loops, wherein the error signal is processed to become the operating signal for the control valves.

**Fuel Oil Viscosity**

In order to control the fuel oil viscosity, loop number 12 has been arranged.

A steady viscosity value is obtained through heating the oil in a heat exchanger. Normally, control follows the system whereby a differential pressure transmitter measures the pressure drop, which is directly related to viscosity and, depending on the signal from the pressure transmitter, steam to the heat exchanger is controlled. With large oil flow this method functions well, but with a low oil flow the system is not inherently stable. There are also flow variations due to the long transport lines involved. To overcome this problem a flow meter is incorporated in the system. Therefore, any variation in oil flow also has an effect on the heating steam supply. Both the flow and viscosity signals are summated in the computer and have an influence on the controller.

**Deaerator**

Loop numbers 13 and 22 control the spill and make up water in the deaerator.

The spill is controlled by a differential pressure sensor measuring the level in the deaerator and when this is higher than the desired value, directs the flow to the distillate tank via a control valve. If the level in the deaerator is low, even though the control valve for drain off of the condensate to the distillate tank is closed, make up water must be provided. This is taken from the distillate tank and flows via a control valve to the main condenser from where it is pumped to the deaerator.

With shut down of the turbine the reduction in condensate flow becomes such that the cooling in the air ejector/gland condenser unit becomes insufficient and damage may result. To correct this condition water is automatically taken from the distillate tank directly to the main condenser. Under fluctuating load conditions in the main turbine the pressure variations within the turbine are used as a signal to influence the control of condensate via the control valve, a low pressure signal initiating recirculation of the condensate through the condenser.

## OPERATOR'S COMMUNICATION WITH THE COMPUTER

The loading of programs and the starting and stopping of programs and control loops, is done through the typewriters. Therefore, all communication, between the operator and the computer, is made via the three typewriters, a tape printer and a tape reader. The typewriters are situated, one each in the machinery space control room, cargo control room and on the bridge.

The operator can, via the typewriter, choose the access performance functions which will, for example, couple in or out, start or stop programs, or change parameters. Such functions, which are fundamental to a particular operation, are barred from any machine except the proper typewriter for the function.

The operator's communication with the computer is initiated via any of the typewriters mounted on the bridge, in the cargo control room or in the machinery space control room.

Initiation of the operator communication is through typewriter keys marked CR (Carriage Return) or MI (Manual

Interrupt). When initiated the writer prints out OP–TIME where time is in hours and minutes.

The operator then chooses the specified function with a code of four letters followed by CR. The code checks that the function is free, accessible and permissible from the typewriter in use.

If not, a fault message is written and communication ceases between the operator and the computer. If the call is legal a lead text is printed out. The operator then answers with the operation required.

The operators call takes the following general form: —

CR or MI (depending on the typewriter keying)
OP–TIME <chosen function (composed of four letters)> CR
Lead text from computer > Operators reply < CR.

The underlined values are written by the operator.

An example of starting of Loop Number 3 at 12.45.

| CR/MI | | Initiation |
|---|---|---|
| OP–12.45 | CLOP CR | Required function |
| LOOP NR. | 03–0 CR | Loop Nr.03. Start op.0 |

Similar codes are used for starting of programs, demand print-out, navigational computations, etc. Three separate program systems are prepared and deposited on paper tape. These are Sea System, Loading System and Unloading System. Function codes are issued to define the program system when communication is started.

During the voyage from Europe to the Persian Gulf the vessel operated with conventional control systems and operated in the UMS condition immediately on becoming operational. The setting up of the computer systems was carried out during the voyage and was at such a stage that when the ship arrived in the Persian Gulf a number of programers were able to leave the ship. Meanwhile the remaining representatives of the shipbuilders progressed the installation and all the programs and loops previously listed were finally made operational during the second half of the voyage between the Gulf and Japan.

In order to avoid system disturbances in any process during change-over from conventional control system to computer control or *vice versa*, the system operator is able, with the aid of a change-over panel in the machinery control room, to check the valve position in the process system. This is done by comparing the analog output signal from the computer for any loop, with the ammeter reading on the change-over panel, which indicates the valve position (Fig. 5).

```
OP    854 CL
LOOP-NR  01-0
OP    854 CL
LOOP-NR  02-0
OP    855 CL
LOOP-NR  03-0
OP    855
KOD UNDEF

OP    855 CL
LOOP-NR  04-0
OP    855 CL
LOOP-NR  05-0
OP    855 CL
LOOP-NR  06-0
OP    856 CL
LOOP-NR  08-0
OP    856
OPR BUSY
CL
LOOP-NR  10-0
OP    856 CL
LOOP-NR  12-0
OP    857 CL
LOOP-NR  13-0
OP    857 CL
LOOP-NR  22-0
OP    857 CS
PROG-NR 22-0
 858
PUMP START
OP    858 CS
PROG-NR 25-0
OP    858
 858S*
MVPV START
*-V
OP    858 CS
PROG-NR 23-0
 859
KYLV START
```

## ENVIRONMENTAL REQUIREMENTS

The results being obtained from this experimental installation are of great interest to the Society as well as the sponsors of the installation and further vital information will be obtained on the important question of applying computers to ship control systems.

As has been mentioned, the computer installed was a basic industrial unit and it will be interesting to discover how this and the peripheral equipment react to a more rigorous enviroment than they would normally be subjected to in industry. One of the basic requirements for the acceptance of control systems and on line process control is that the operation should be reliable. This means that sensory devices, loggers, printers and the computer itself must operate with a

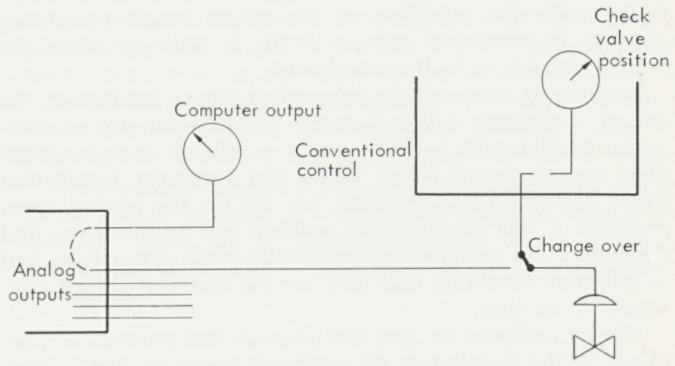
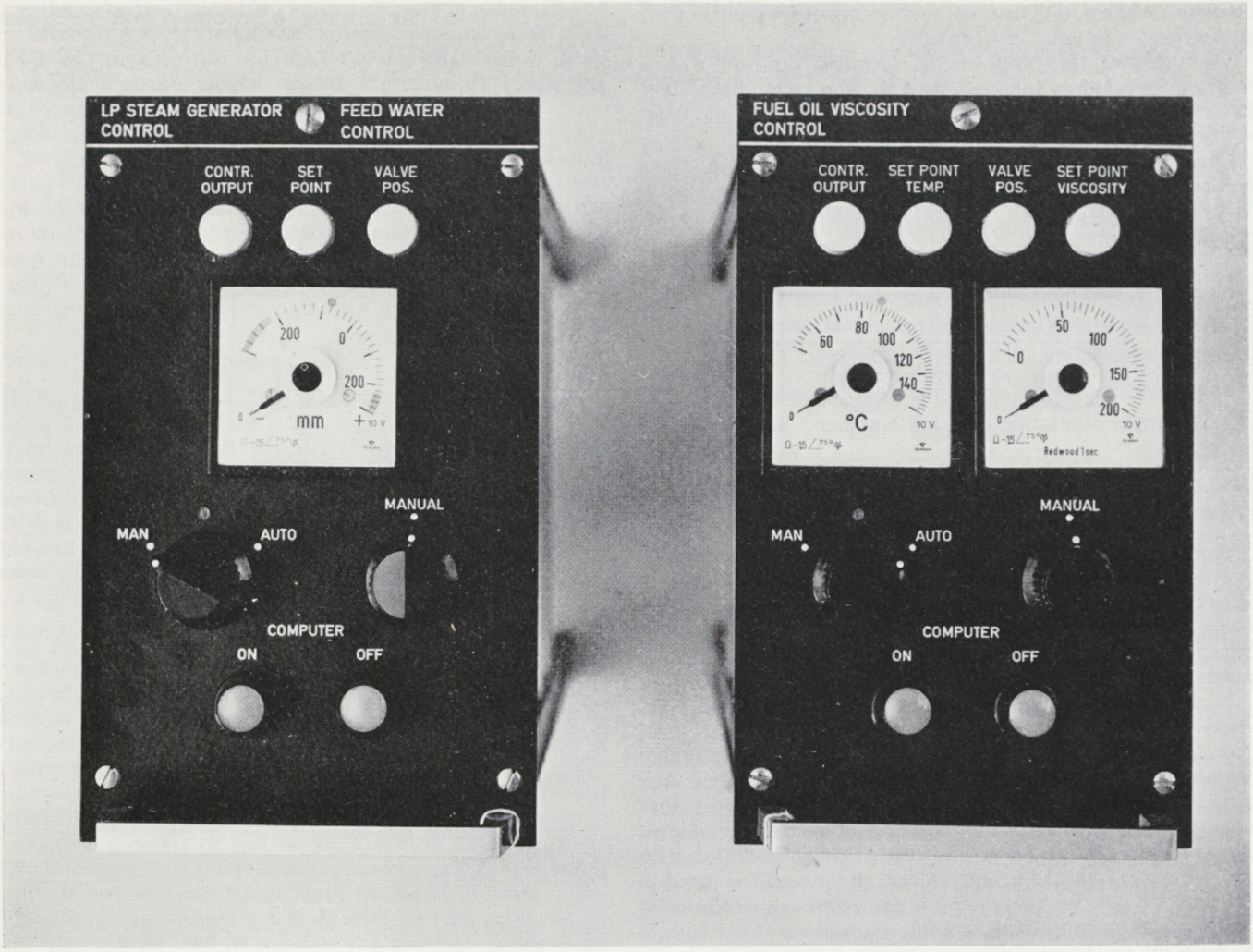



FIG. 5




Detail of changeover panel in engine control room.

minimum of maintenance and a maximum of reliability to eliminate expensive shut-down time.

This computer installation was completely backed up by conventional control systems. This, of course, means that the complete installation for the control applications was expensive and in order to make the computer application commercially viable the reliability of the system would necessarily need to be confirmed beyond doubt in order to allow the back-up system to be dispensed with.

Looking at some of the physical problems influencing the use of computers, it is a fact that the physical size of computers has been to a large extent a militant factor against their use on board ships. Whilst the computer installation under discussion was, in effect, too big for the control room in which it was situated, this problem can be overcome and computers are available of sufficiently small dimensions and of sufficient flexibility that they can be mounted almost anywhere in the ship.

Having accepted the fact that physical size presents no problems to the installation of computer based on line control systems the realities of the environment must be considered and the Society are, on the basis of the experience already to hand, able to produce guidance notes on the construction and installation of computers for use in ships.

The special problems associated with this type of equipment can be summarised as follows: —

(1) Marine environment.

(2) Electrical power supply.

(3) Electrical interference.

(4) Lack of specialist operators and on the spot complex maintenance facilities.

In general the equipment must be constructed and installed to prevent damage from shock, vibration and ship motion, and should be installed in suitable conditions away from excessive heat, moisture and dirt and be protected from mechanical damage. Cooling air for the computer and any other units needing forced cooling should be clean and dry. Maintenance should be mimimal, whilst the vessel is at sea and should be able to be carried out by replacement or simple adjustment.

## ENVIRONMENT

An ever present problem is that of vibration and this must be recognised by designers who are more than likely to be designers primarily for industrial installations. Position of installation on board must therefore also be considered and suitable mounting arrangements made to alleviate vibration effects. Ambient temperature can be more easily taken care of in the suitable siting of the equipment and much can be done to eliminate high ambient temperatures. In addition the high temperatures generated in the computer must be dissipated and air conditioning systems may be necessary to give the clean dry conditions necessary for this cooling air.

The computer in the system under consideration was mounted on vibration mounts in an air conditioned control room in the machinery space. Back up air conditioning was installed, and during the 19 days between the Gulf and Japan the control room ambient temperature was in the order of 28–30°C whilst the machinery space thermometer recorded temperatures in the region of 42–45°C. Vibration in the loaded condition was not a problem on board, but I understand that in ballast condition vibrations in certain areas was considerable and time will bring to light any possible problems from this quarter.

## ELECTRICAL POWER

By its nature of being a self-contained, relatively small, power supply, the power plant aboard a ship will, in general, tend to vary more in voltage and frequency than is normally the case with land-based power installations. The computer should, therefore, be designed to operate satisfactorily with variations from normal values of voltage and frequency. For example the equipment should operate satisfactorily for steady state voltage variation from normal values of +6 per cent and −10 per cent, some authorities quoting figures of +10 per cent and −15 per cent and on alternating current systems, a simultaneous frequency variation of ± 2·5 per cent.

Possible transient voltages and switching surges must also be designed for.

The possibility of complete loss of power is an ever present prospect in ships and any computer installation must be prepared to cope with them. In order to achieve this the system designer must consider the protection of the hardware from damage due to power stoppage and provide an adequate start-up facility after shut down.

## ELECTRICAL INTERFERENCE

It is essential to try and ensure that all signals are as free from noise as possible. To limit interference it will be necessary to ensure that the layout and spacing of signal cables in relation to power cables is carefully considered.

Another potential interference problem, which is particularly present aboard ships, is that of earth loops and earthing of circuits and cabinets must be carefully considered to minimise this problem. Care should, therefore, be taken at the design stage and during installation of a computer system to try and ensure that:—

(1) All signal cables are kept as short as possible.
(2) Signal cables be strictly separated from power cables and run on separate cable trays.
(3) Multiple earthing should be avoided.

## MAINTENANCE

The philosophy of land-based computer installations ashore, where the maintenance engineer is only hours away from any installation, and where preventive maintenance and testing can often be carried out, daily if necessary, cannot be applied to installations in ships.

Short-haul ships making regular calls at ports, where a qualified maintenance staff can be on hand, could probably ensure trouble-free operation at sea for a week or two after port servicing. However, a different philosophy must be used for vessels operating on long trips and away from recognised service centres. It is essential that maintenance carried out on board must be kept to a minimum and that the ship's crew, have the assistance of self-diagnosing features in the system and that repairs be carried out by replacement or simple adjustment.

The installation of completely reliable equipment in the first place, however, coupled with adequate commissioning time will ease the problem of failure and is of vital importance in such complex installations as the type described.

## ADVANTAGES OF AN ON LINE COMPUTER CONTROL SYSTEM

Experimental installations of this type are being installed or already operating in other European countries and Japan and consideration must be given to whether the high cost involved is warranted since the computer installation is being asked to perform functions which are similar to conventional systems built up of individually wired fixed circuit units.

Some of the operational and technical advantages of an on line process system are:—

1. Alterations of programs can be easily carried out to change the nature and duties of the process requirements. This can be done without recourse to wiring alterations necessary with systems where the circuits are designed and physically wired to perform a single duty in a fixed pattern. Programs can also be extended when required.

2. The expenditure on instrumentation could be considerably reduced, since logic interconnections are already available in the store via the program. The reduction in hardware thereby obtained is achieved by multiple use of the arithmetic unit, storage and control unit. The cost of instrumentation could possibly be in the order of 50 per cent of that of a functionally equivalent, permanently wired installation. Reducing the amount of hardware used, should also have the advantage of increasing the overall reliability of the system.

3. Maintenance and servicing of the computer-based control system should be eased in that one has standard units in the computer which can be checked by means of test programs without any knowledge of the technology of the process being controlled.

## CONCLUSION

The duty of the computer is in its present stage of development, an alternative to the instruments, controllers and "black boxes" now performing usefully and successfully in control systems operating on a wide scale in the operation of ships at sea.

It will, therefore, be required to confirm its role as a variable program central data processing, control unit with the added advantage of having greater flexibility and increased system reliability.

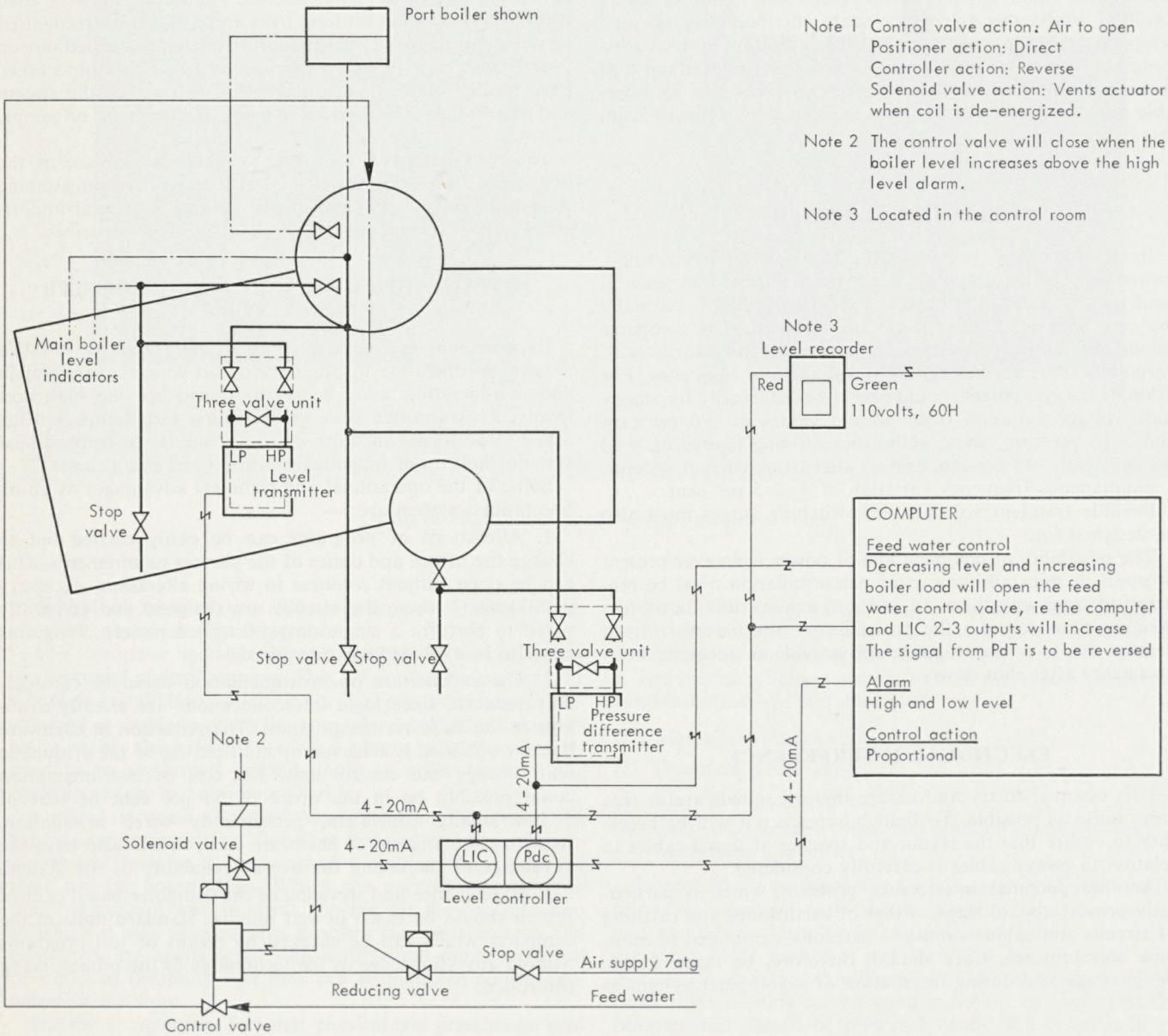
If these conditions are satisfied, and computers as they certainly will, become cheaper and smaller in size, the next few years may see more installations of this nature being used for the special programs required for tankers and refrigerated vessels.


## ACKNOWLEDGMENTS

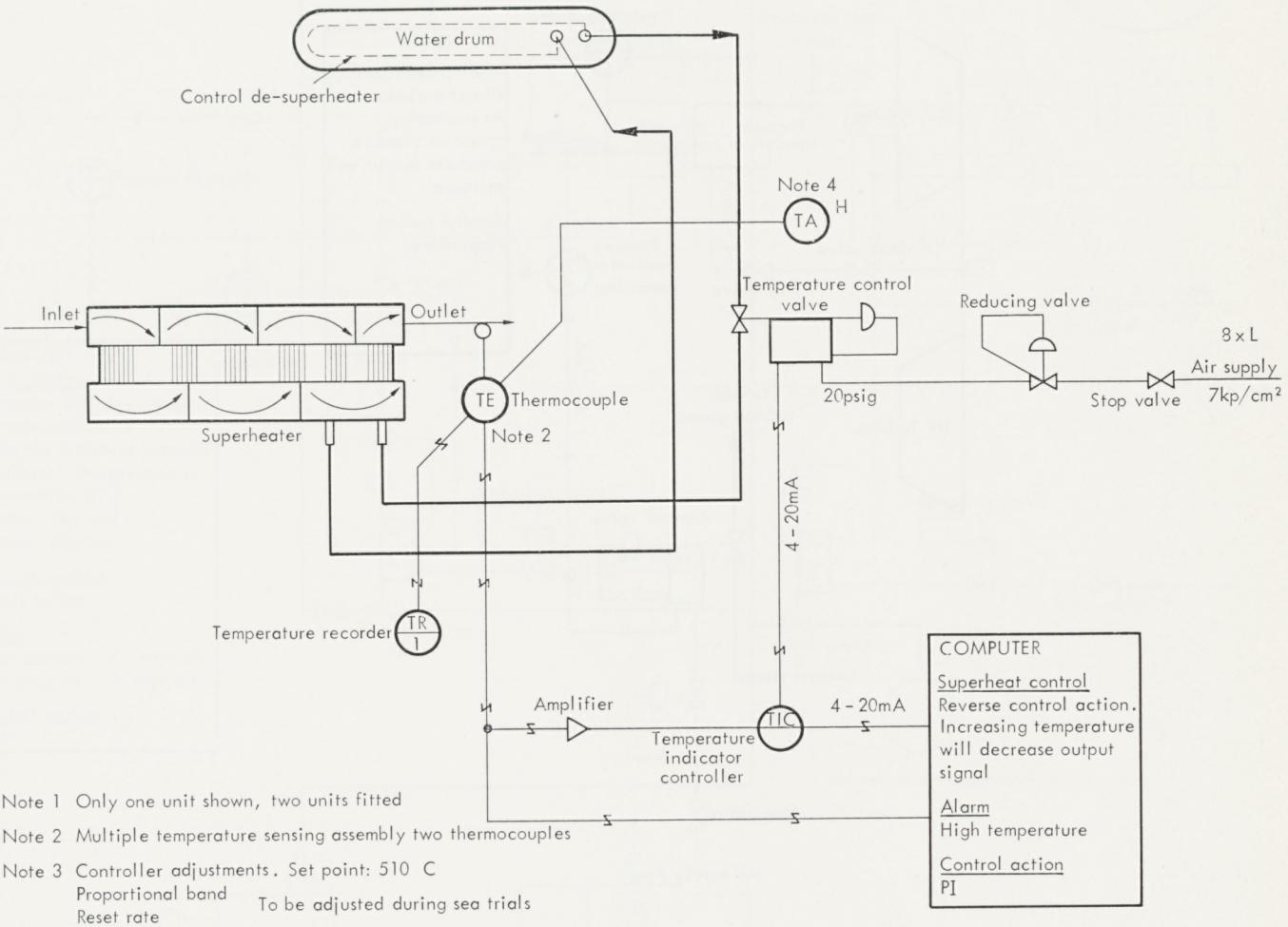
The Author wishes to acknowledge the help of Messrs. Kockums and ASEA for the provision of technical information and photographs.


# APPENDIX

A number of the machinery control systems showing how the computer is used in the control scheme have been included as a point of interest.




Boiler water level control.




Note 1 Only one unit shown, two units fitted

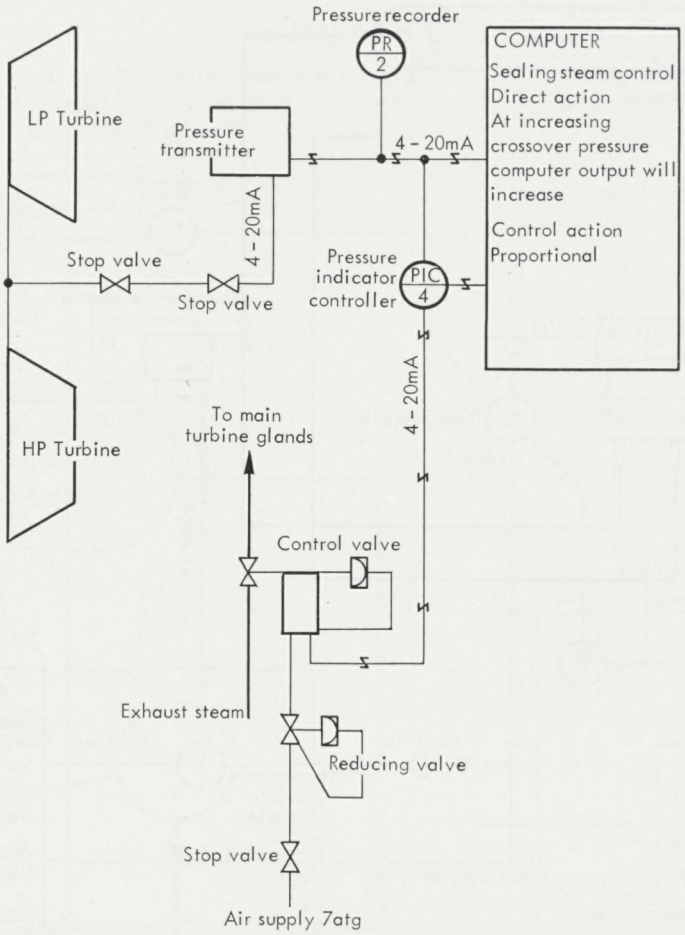
Note 2 Multiple temperature sensing assembly two thermocouples

Note 3 Controller adjustments. Set point: 510 C
Proportional band
Reset rate
To be adjusted during sea trials

Note 4 Set point: 520 C

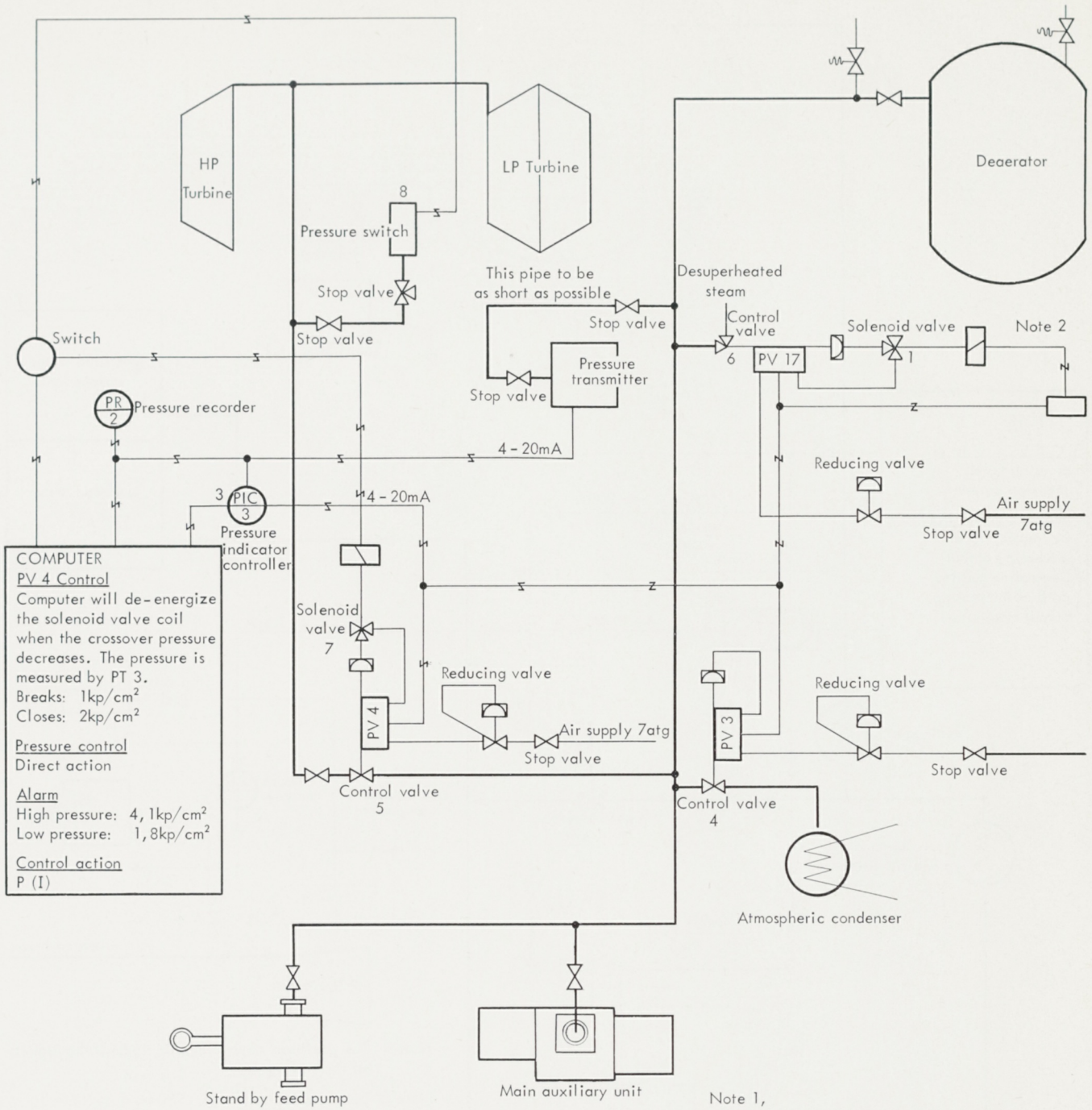
Note 5 Control valve action: Air to close
Controller action: Reverse
Positioner action: Direct

Main boiler superheat control.




Note Control valve action: Air to open
Positioner action: Reverse
Controller action: Direct

Gland steam control.

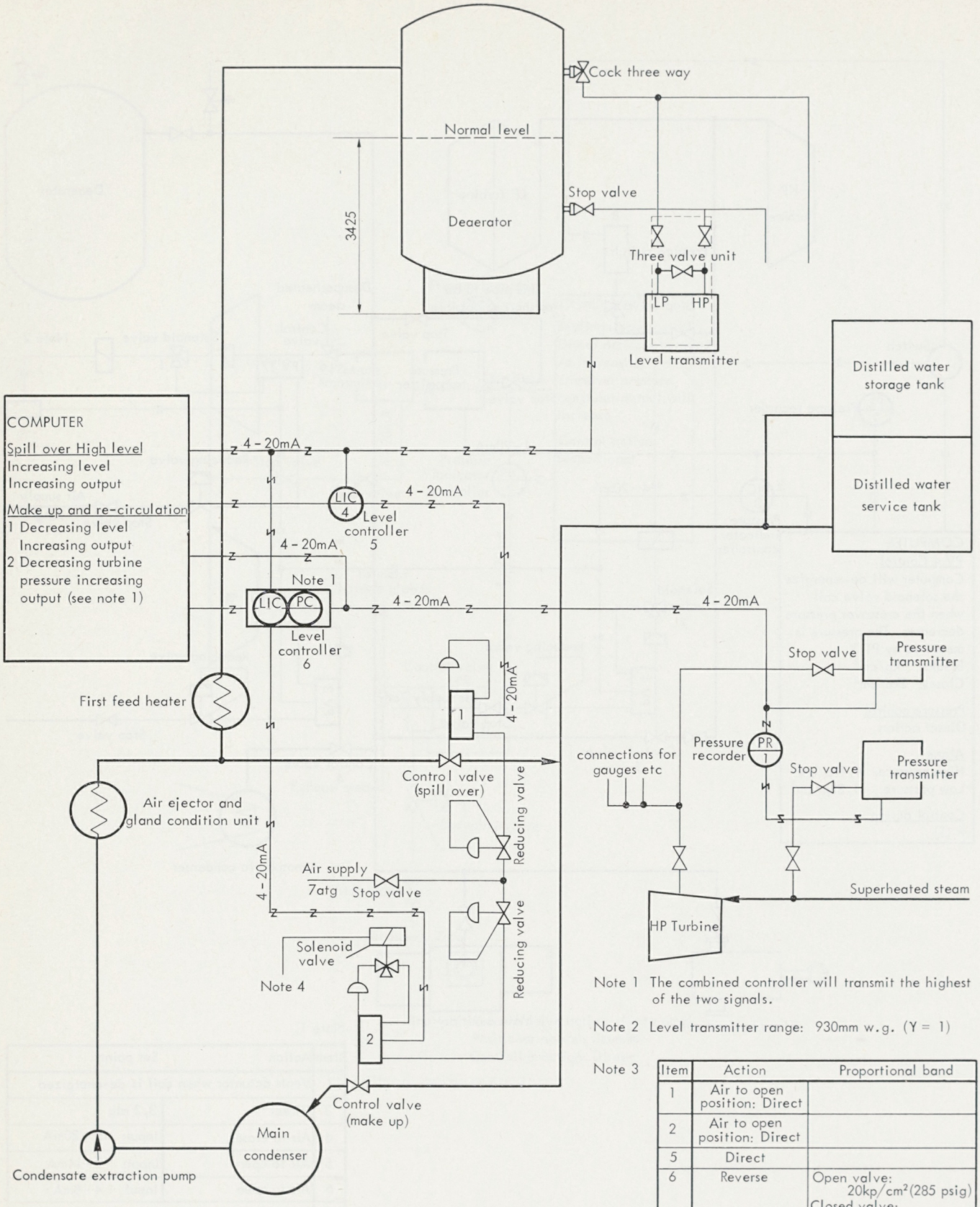



Note 1,

| Item | Action | Set point |
|---|---|---|
| 1 | Vents actuator when coil is de-energized | |
| 3 | Direct | 3, 2 atg |
| 4 | Air to close | Input: 15 - 20mA |
| 5 | Air to open | Input: 9 - 14mA |
| 6 | Air to open | Input: 4 - 8mA |
| 7 | Vents actuator when coil is de-energized | |
| 8 | Breaks on decreasing pressure | |

Note 2, The solenoid valve to be de-energized at PV17 input failure.

Exhaust steam system control.




Note 1 The combined controller will transmit the highest of the two signals.

Note 2 Level transmitter range: 930mm w.g. (Y = 1)

Note 3

| Item | Action | Proportional band |
|---|---|---|
| 1 | Air to open position: Direct | |
| 2 | Air to open position: Direct | |
| 5 | Direct | |
| 6 | Reverse | Open valve: 20kp/cm² (285 psig) Closed valve: 10kp/cm² (142 psig) |

Note 4 If both condensate pump stops and control valve item 2 is to be closed by de-energizing the solenoid valve. Signal from LS 4

Deaerator level control automatic recirculation.

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*Lloyd's Register Staff Association*

# SOME DEVELOPMENTS IN THE MINISTRY OF DEFENCE

K. J. Rawson

Paper No. 6. Session 1970-71

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# SOME DEVELOPMENTS IN THE MINISTRY OF DEFENCE

by K. J. RAWSON*

**Introduction**

1. In selecting a subject for this paper it occurred to me that the important technological advances in the Navy Department would already be very well known to members of Lloyd's Register Staff Association. Indeed, in such fields as the finite element approach to structural strength there has been very active co-operation between mercantile and warship interests, as has taken place also over the years with steels and welding. Advances in ship propulsion plant and electrical and control systems have already been the subject of erudite papers to the learned Institutions and will be well known as a result.

2. There are occurring in the Ministry of Defence, however, more subtle changes in outlook and technique which I thought that you, as material managers and taxpayers, might find of interest.

**The wind of change**

3. There are probably four major factors which have brought pressure to bear on our traditional manner of doing business.

(a) RECRUITMENT. Even with their handsome new rates of pay, the Services are not popular employers. Family disruption, the popular image of idiot discipline and the reaction to the Viet Nam horrors all make a recruiter's lot not a happy one. However, the most important recruitment difficulty derives from the impending raising of the school leaving age and the expansion in higher education. Fig. 1 shows from demographic studies that the population from which the Navy draws its recruits reduces by about one-third between 1966 and 1976 (Ref. 1). What it does not show is that those who are now able to benefit from university style education are that intelligent group from which are drawn those able senior ratings who have long formed the backbone of the Navy. Thus not only are the numbers falling but the general level of ability of ratings will fall over the years. Actual recruiting for all three services, required at the rate of about 45,000 per year, was (Ref. 2):—

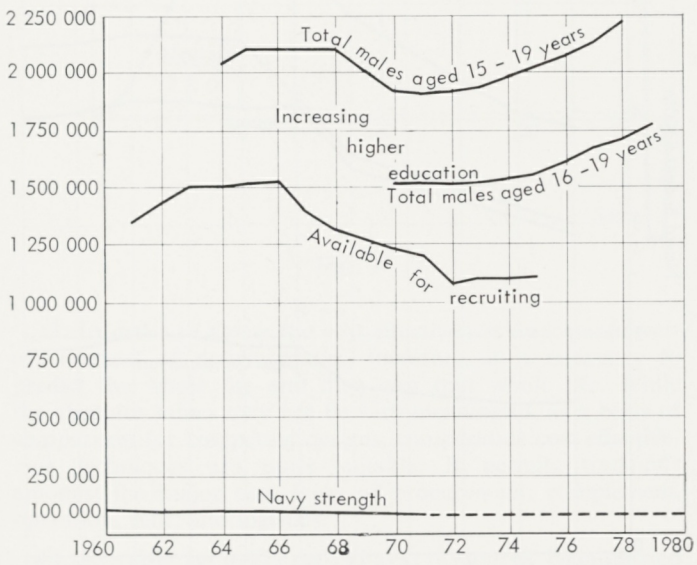


FIG. 1

1967 — 40000
1968 — 32000
1969 — 28000
1970 — 34000

(b) COMPLEXITY. The applied science which has become war, advances at an alarming rate. Each additional sophistication generates a new counter sophistication. The cost of providing armament in a modern frigate constitutes 60 per cent of the production cost. Today's tracking radar for the Sea Dart system, for example, has eight times as many components as that for 1965's Seaslug system (Ref. 3) and cost seven time as much to develop:—

| | Total components | Components for Self monitoring |
|---|---|---|
| Type 901 | 12500 | 4000 |
| Type 909 | 100000 | 30000 |

(c) MANAGEMENT. The Fulton Report (Ref. 4) was critical of some aspects of management in the Civil Service, a part of which plays an important part in the design and support of the Navy's matériel. The "new" science of management has exploded into a wealth of paper, mushrooming consultants, experts and charlatans, good ideas and blind alleys, re-training and misleading, bewilderment and enthusiasm. New phrases and slogans now drive us onwards like the Gadarene swine, destroying good and bad alike. What this explosion has achieved is a fundamental re-appraisal of much that has—like the value of experience, for example—been taken for granted.

(d) FINANCE. Both major political parties have laid extreme emphasis upon financial restraint in Defence. This was not always so. While the Admiralty finance officer, since the days of Pepys, was answerable at the bar of the House, this was basically to account that money had been spent without carelessness or corruption. The designers were, in fact, given a free hand to demand best quality because that was what they wanted and what, therefore, *had* to be paid for. Under severely limited finance, the simple demand for technological excellence is no longer adequate.

4. There are other factors, both social and technological, which are effecting change, but these four are having the most profound influence upon thought. The Navy Department is also in the unique position of being designer, owner, repairer, chandler, agent and broker. Its interest in its ships is total and extends over their whole lives. The philosophy by which it manages its ships should therefore be all embracing.

* Member, Royal Corps of Naval Constructors, serving as Assistant Director of Naval Administrative Planning.

**A new philosophy**

5. Accustomed as we are to Consumer Magazines and television commercials we should have no difficulty in stating the philosophy in accordance with which we should run a Navy. It should be the best that money can buy. It should give value for money. It should be an effective fighting force. With a little thought we might end up with: —

> "The Royal Navy should provide the highest level of effectiveness possible within the financial and manpower constraints placed upon it by the Government."

In other words, value for money and value for men. But whether we call it best or value or effectiveness, it still has to be defined with some more precision.

6. The most generalized definition of effectiveness is, in terms of set theory, the union of capability, dependability and worth: —

$$E = (\text{capability}) \cup (\text{dependability}) \cup (\text{worth}) = CUDUW$$

Divided by cost, F, this becomes cost-effectiveness $= \dfrac{CUDUW}{F}$

Divided by personnel numbers, it becomes manpower-effectiveness.

*Capability* describes the potential performance of the Fleet in all its roles.

*Dependability* describes the ability to adopt a capability at any instant and to continue it in a specified time pattern. The element of dependability which is simply the fraction of a specified time for which a capability is possible is called the *availability*.

*Military worth* is the military return under specified circumstances on an investment in a capability.

7. If we were to apply this philosophy to the ownership of a hot-dog stall, its capability would be the serving rate of hot dogs, its availability would be its opening hours, and its worth would be dependent upon the acceptability of its flavours and its pitch near a theatre queue. Its effectiveness could thus be largely quantified. So could its costs. The numbers and sizes of vans, their mobility and locations, manning, range of products, maintenance and re-stocking periods and other features could be varied in order to plan the most cost-effective combination.

8. The Royal Navy is not quite so easily quantified. Nevertheless the mere adoption of a policy of cost-effectiveness introduces a healthy air of enquiry. Should we any longer rely wholly upon the designer's, or the Naval Staff's, or the dockyard's or anyone else's idea of what is "best"? We have now the beginnings of a tool which can actually demonstrate that one course of action is superior to another. The great advantage is that we do not have to quantify every element of E before we can examine the changes in it wrought by different policies. Thus, we can, keeping C and W constant, optimize $\dfrac{D}{F}$ and this, at present, is a very profitable area.

9. We can also examine $\dfrac{E}{M}$, manpower effectiveness and where the constraints are severe, optimize C/M or D/M, M being the number of men.

10. The real point about this approach is its numeracy. We are forcing measures into a field which has previously been governed by emotion, intuition, seat-of-the-pants management, engineering judgement and hierarchical wisdom. By displacing these features, we certainly lose something important. Leadership qualities today are under-valued. Decisions about national defence, based exclusively upon cost-effective analysis, are barren. However, the introduction of numerate cost-effectiveness and manpower-effectiveness analysis cannot fail to increase the chances of better decisions, at least strongly influenced by those constraints placed upon us by Parliament. Moreover, this discipline is applicable to whole fleets, complete ships, individual equipments and small components and can, therefore, make individual designers clearly cost and manpower conscious.

**Whole life costs**

11. For many years warships have been acquired at the minimum reasonable production cost for which the designers consider their product to be technologically acceptable. This is because Parliament allocates its money annually and the scrutiny of the defence budget is aimed at paring the next year's estimates to a minimum. There is thus very little incentive to make an investment now in order to save money in a few years' time. Yet the scope for this is large. Fig. 2 shows a rough breakdown of the Navy budget over the years. The cost of supporting the Fleet accounts for nearly one half of the Navy's money. In 1970-71, the money allocated to the Chief of Fleet Support is about £260m and a great deal of the other material overlord, (the Controller)'s money is also directed towards support.

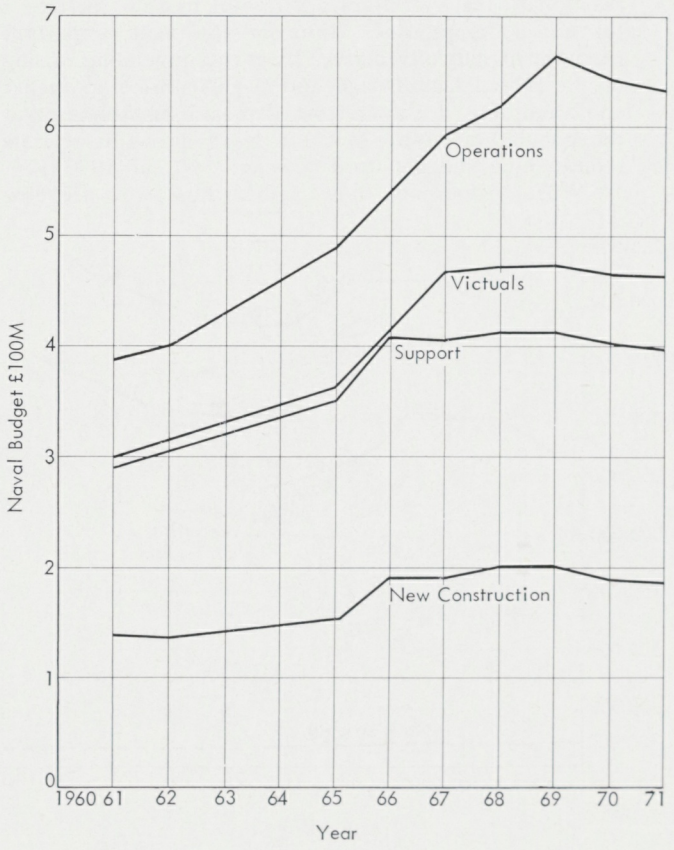


FIG. 2

12. Upkeep costs are very largely committed during the concept and design stages of a ship. Once the ship is designed there is little that can be done about changing its support costs. It is not unreasonable, therefore, to commit these costs with deliberation. With a five to ten year time lag between design and support, this means using good predictive techniques. Life costs of a frigate costing £10m to build are probably of the order of £60m at current prices. This is spread roughly as shown in Fig. 3.

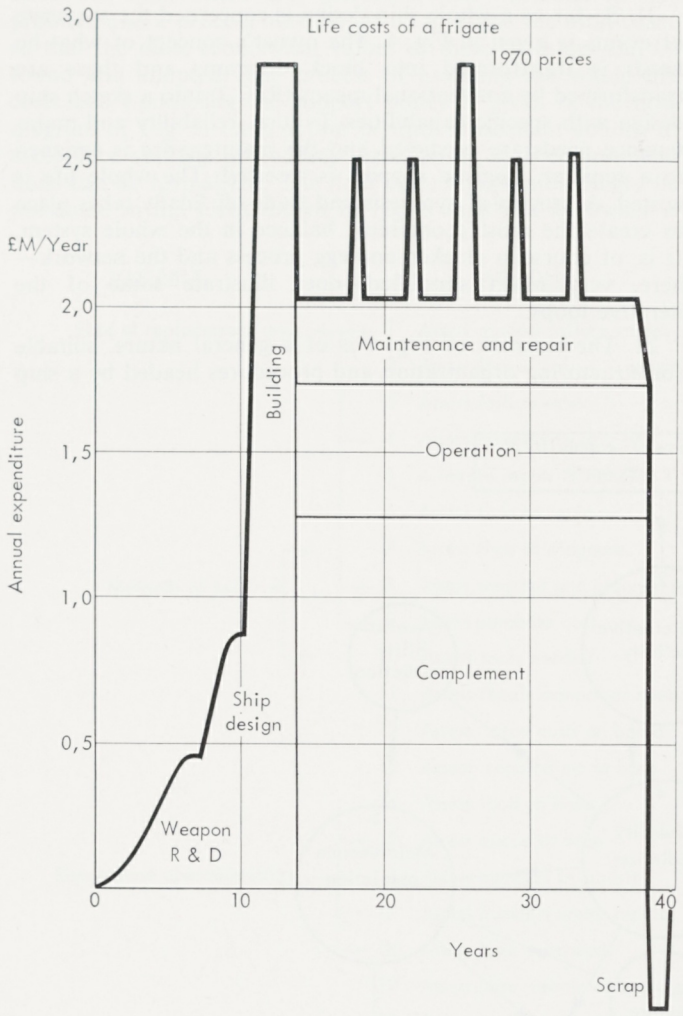


FIG. 3

13. In order to assess the cost-effectiveness and manpower-effectiveness of design studies, therefore, it is necessary to predict the whole life and then cost that whole life. While the absolute values may not be very meaningful, as a basis of comparison for competing designs, comparative cost effectiveness techniques are quite suitable. It permits trade-offs amongst the major cost areas of procurement, complement, operation, refit, and logistics.

14. Exercises on a like basis have, of course, been carried out for many years for merchant ships to a limited extent. The profit motive is a highly numerate master to serve and discounted cash flow exercises are a good deal more appropriate than they are in defence spending. Contrasts between warships and merchant ships probably raise more questions than they settle. It is worth noting, however, that the 40,000 dwt. bulk carrier given in Ref. 5 shows a wages bill of $2\frac{1}{2}$ per cent of the first ten years' costs, while Fig. 3 shows complement to account for about 30 per cent.

**Experience in the U.S.A.**

15. There is a genius in the U.S.A. for developing ideas to their ultimate state very rapidly. Under Robert MacNamara this happened to the concept of cost-effectiveness without examining the cost- and manpower-effectiveness of cost-effectiveness analysis itself. There sprang up large organisations dealing with every aspect. Today, we are faced with a vast literature concerned with systems engineering, value engineering, management science, system effectiveness and a myriad of minor techniques. The U.S. Department of Defense adopted Total Package Procurement which is a technique whereby the whole life of an entire fleet is predicted and costed in very great detail by contractors and a single gigantic contract placed on the basis of the tenders.

16. Doubts about the total wisdom of these policies are now widespread (Ref. 6). The paper embodying the tenders for one class of frigates sought under the policy of Total Package Procurement weighed in at a little over seven tons. The programmes associated with the F-111 and the C5-A have not escaped the notice of a critical press.

17. Probably the most aggravating import from U.S.A. is the language in which much of the subject is wrapped. My favourite quote comes from a journal describing how to organise the men to deal with concept design:—

> "The responsiveness to concept formulation requirements can be evaluated by the recognition of required capabilities, their organizational location and the guidelines for their compatibility attunes the responsibilities of the participants."

In other words, everybody should know what he is doing.

18. In these circumstances it is not easy to persuade the top management of our Ministry of Defence that cost-effectiveness is a sensible objective. They are naturally deeply suspicious that any agreement to such an objective will open the flood gates to the bureaucracy which has obliterated so much of the very real progress made in the U.S.A. For real progress there has been and, in view of the factors of change with which I began this paper, there is no doubt that we must tread the same path. What we must seek, perhaps with the help of the British genius for compromise, are the most profitable areas. We must, at least, begin to forge some of the tools which will give us the benefit of choice. It is some such tools that I now want to discuss.

**Whole life prediction**

19. If the whole life of a ship is to be predicted it must first be described in elements which are susceptible to predictive technique. The characteristics which determine the support costs whether it be equipment or ship are:—

(a) How often it will break down. This is its *reliability*.

(b) How long before it is beyond economical repair. This is its *wearout*.

(c) How often servicing is required. This is its *planned maintenance*.

(d) How quickly it can be repaired
(e) What facilities are needed for repair
} This is its *maintainability*.

(f) How many spares should be provided
(g) What it consumes
} This is its *logistic support*

(h) How many men to repair, service and operate
(i) What skills and training do the men need
} This is the *manpower support*.

(j) How long may it have to wait for repair.

This is a *queueing problem*.

By measuring its needs in these terms, a designer will be able to predict for the owner.

(k) How much it will cost over its whole life
(l) What men will be needed for what times
(m) What facilities are needed at what utilization
(n) What risk of spares stock out is likely
} These are *ownership costs*.

(o) What availability for duty is probable.

This is *dependability*.

Thus are two of the four elements of the cost-effectiveness equation predicted—dependability and life cost. The other two, capability and worth are determined by operational research techniques and are beyond the scope of this paper.

20. As an intimate part of the design process therefore, each of these characteristics must be predicted in a numerate form. They must then be traded off one against the other to give the best mixture—in other words to optimize D/F. For example, it may be economical to duplicate an equipment in order to avoid carrying a maintainer on board; or it may be worth keeping a high level of spares to take advantage of a slow, cheap, repair facility. Again, higher, more expensive skills may be avoided by obviating diagnosis by a repair-by-replacement policy.

21. So far as a whole ship design is concerned the sequence of events is given in Fig. 4. The owner's concept of what he needs is transformed into block diagrams and these are transformed by conventional means (Ref. 7) into a sketch ship design with specific capabilities. In turn, reliability and maintenance needs are predicted and the maintenance is assigned to a repairer. Logistic support is assessed. The whole life is costed. A process of synthesis and trade-off finally takes place to create the most economical balance in the whole system. It is, of course, a chicken-and-egg process and the network—here, very much simplified—does illustrate some of the iterative loops.

22. The network of Fig. 4 is of a general nature, suitable for structuring organization and procedures headed by a ship

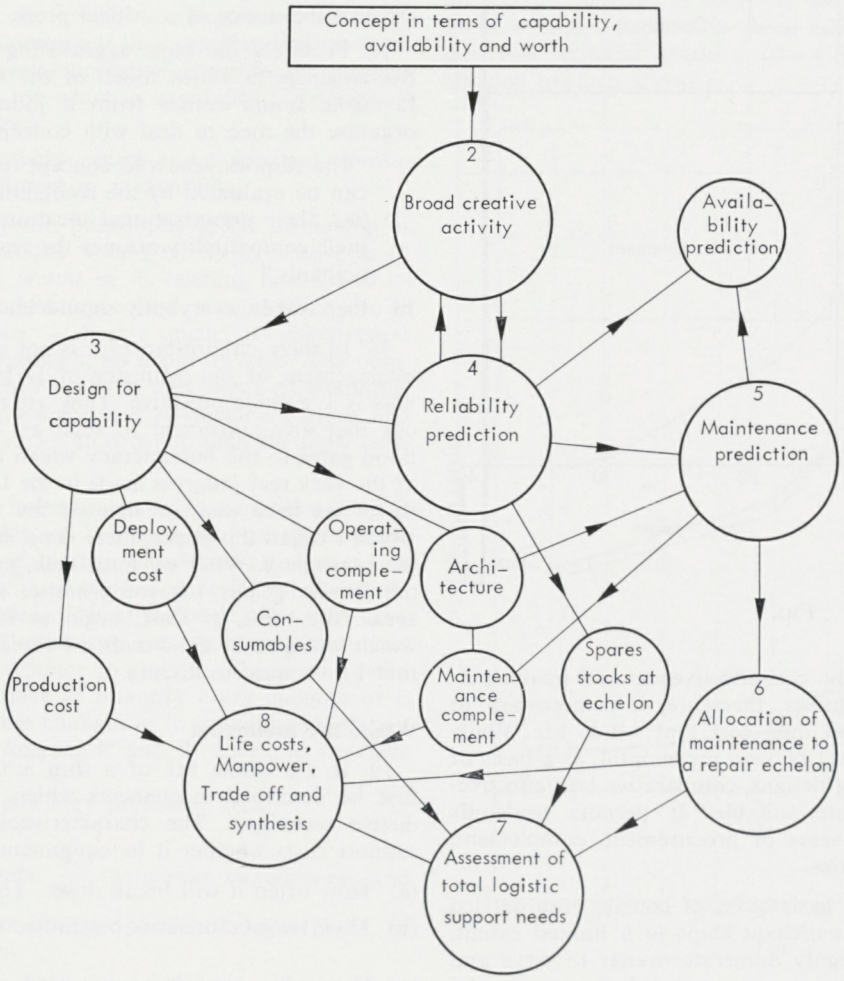


FIG. 4

design project manager. The problem facing a designer of an equipment is more intimate. He has open to him, perhaps, two choices: —

(a) In what size of removable units should I design my equipment?

(b) What test equipment should I design to go with it?

At the same time, the repair base manager may be able to set up several repair lines and the logistician has a choice of stock out risk. There are, therefore, four variables in this problem and a process must be set up to assess the total costs, so that the most economical values of these variables can be found and adopted. The process of assessing the whole life costs and optimizing the support policy is given in the flow diagram of Fig. 5. Each action permits subsequent actions to take place and the procedures for effecting such communications can be formalized. The final trade-offs possible might be presented in the form shown in Fig. 6 in which an owner is presented with a fully costed series of options in terms of the four variables.

Whether it be an equipment or a ship, and however different the procedures turn out to be, the objective is quite clear in both cases. It is to achieve the highest level of effectiveness with the maximum economy of money and manpower over the predicted life.

But is the effort put into this achievement worthwhile? In other words, how cost-effective is the process of achieving cost-effectiveness?

23. Purely in financial terms, all that we must show is that the value of these exercises exceeds their costs. It is a fact that we at present spend pitifully little on the early design stages of our warships, at the end of which most of the characteristics which determine the support life—architecture, complement, duplications, choice of machinery—are committed. During the sketch design probably some 20 man years of effort valued at £50,000 are used. In the case of a class of

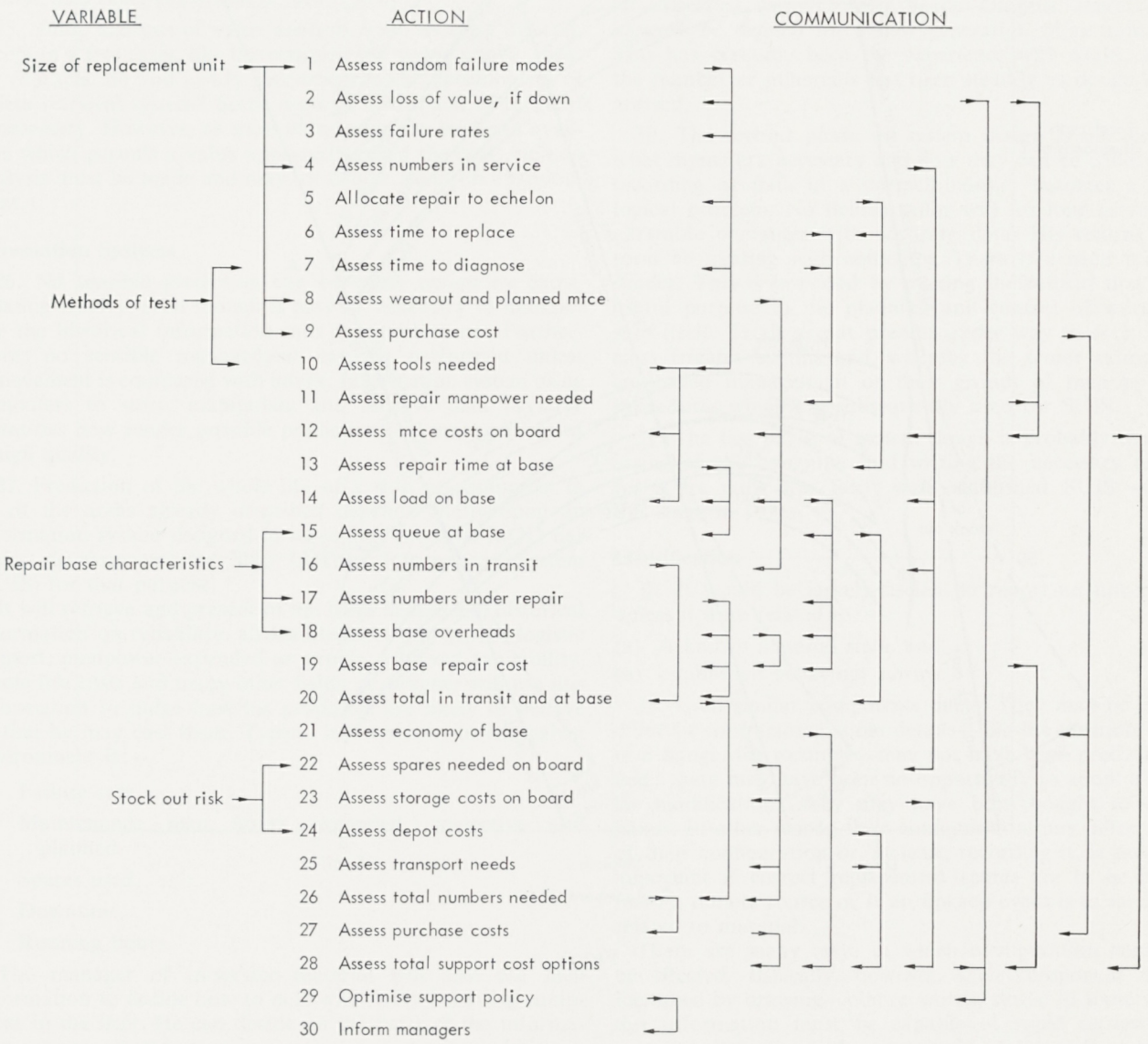


FIG. 5

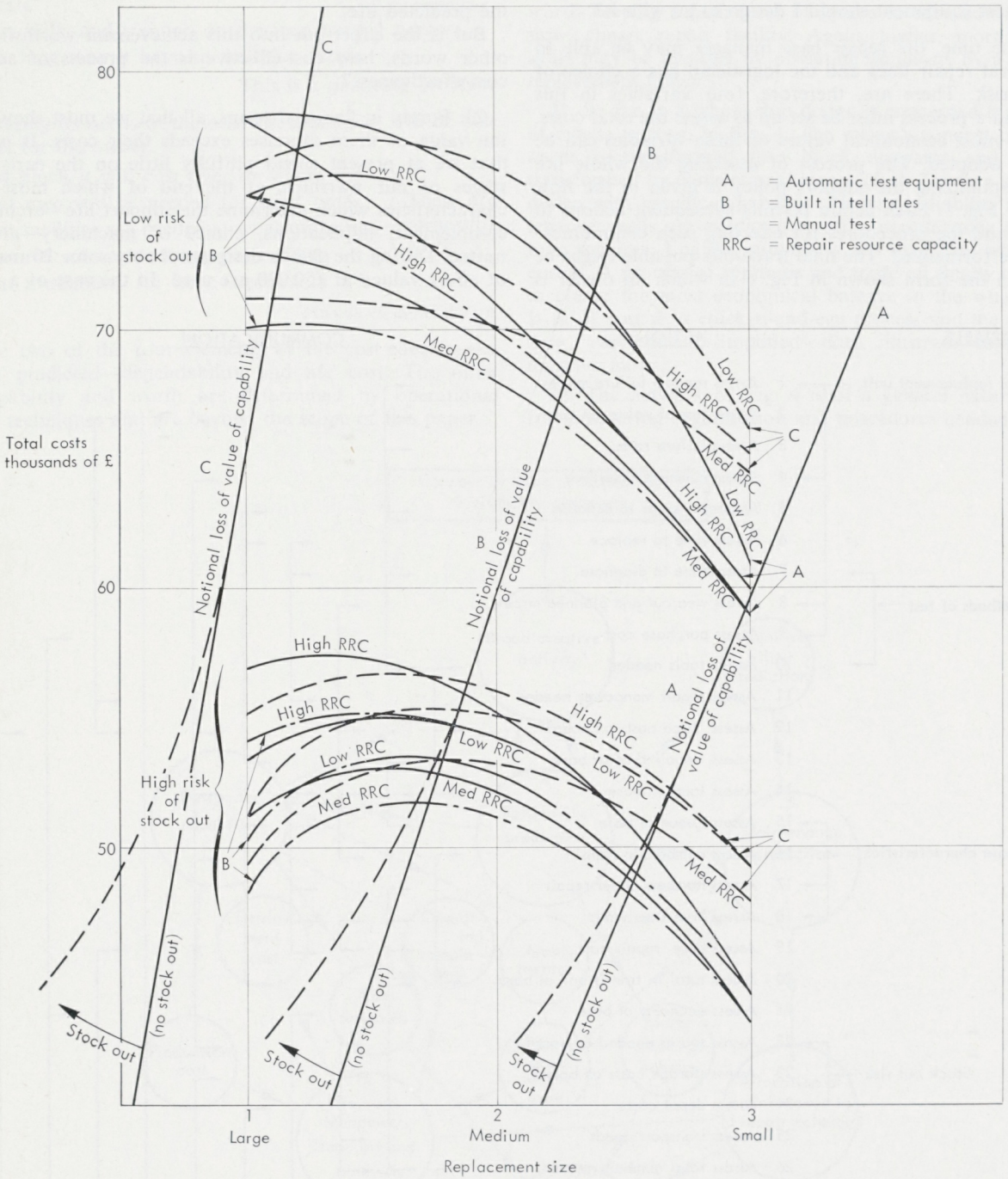
A = Automatic test equipment
B = Built in tell tales
C = Manual test
RRC = Repair resource capacity
Total costs thousands of £
80
70
60
50
Low risk of stock out
High risk of stock out
Low RRC
High RRC
Med RRC
Notional loss of value of capability
(no stock out)
Stock out
1
Large
2
Medium
3
Small
Replacement size

FIG. 6

20 frigates, this would commit about £1,200,000,000 of whole life costs. Of this £400m are attributable to the complements and £275m to refits.

24. The cost committed by one man in the complement of 20 frigates for 20 years is about £2m of today's money. Thus, it could be economical to spend £2m in the design stages on automation or exotic material to render him unnecessary. Yet we spend only one-twentieth of this on the entire ship sketch design. Thus, some at least of the processes of Figs. 4 and 5 are justifiable. Processes to reduce refit time are also likely to be highly profitable investment areas. Unfortunately, the severe constraints imposed upon the Civil Service in respect of money and manpower, encourage the abandonment of the research which would lead to economies far in excess of the savings which those constraints impose. Blind constraint of this sort encourages the conventional. Furthermore, it encourages investment in research justified in terms of very broad respectable-sounding objectives, mainly in the general management field; "management by objectives", "accountability" and "cost-effectiveness" are typical.

25. Value analysis of value analysis is exceedingly difficult, except in a few cases, like the complement saving above. How, for example, do you justify investment in the development of a data retrieval system? Some inspired investment of this sort is necessary. However, as soon as information becomes available which permits a value appraisal against the cost, such an analysis must be made and may, of course, result in abandonment.

**Information Systems**

26. No sensible prediction can be made except by extrapolating history, even though it may be necessary to manipulate the historical information into a suitable form. Furthermore, no sensible management can be performed unless achievement is compared with intent. Information system using computers to store, manipulate and retrieve data in large quantities now render possible prediction and management of a high quality.

27. Prediction of the whole life of a ship or equipment in all of the areas already described depends vitally upon an information system designed to serve that end. The MOD has under development the Ship Upkeep Information System (SUIS) for that purpose.

It will retrieve and present in the form demanded, historical information on reliability, all maintenance and repair, logistic support, manpower expended on repair, achieved availability, whole life costs and many other fields. A designer will use this information to judge how his proposals are likely to behave so that he may cost them. Typical information stored against environment is:—

Failure rate.

Maintenance man hours expended, corrective and planned.

Spares used.

Downtime.

Running hours.

The manager of in-service material will also use such information to decide how to deal with badly behaving equipment in the fleet. He can decide on the basis of the information returns, whether it is economical to scrap it, re-design it, duplicate it, increase the maintenance effort, increase the spares provided or ignore it. On a well behaved equipment, he may be able to reduce the costs if the information indicates over-provision.

28. Similar information is needed to control work in the repair establishments. Managers at all levels require a regular comparison of achievement with the plan if they are to be in a position to take knowledgeable corrective action. Information systems are therefore being developed in the dockyards both to retrieve data for job planning and scheduling purposes and to effect control during production. The information needed by SUIS is fed in from these sources; common identification is, of course, very important in this respect.

29. It would be foolish to underestimate the difficulties of introducing information systems. They must be structured from their required output and their output must serve a clear objective. Our objective I have already outlined. It is not always easy, however, to persuade men who are set in their ways that their engineering judgement would be improved by more factual information or that their experience is stored in an imperfect way—in their heads. Outputs, therefore, may have to be defined for a new generation of re-trained men. This has certainly been the experience with SUIS, although the number of adherents has risen steadily as design has progressed.

30. The second phase of system design is deciding upon what inputs are necessary and how they can be collected. The recording of data in a correct manner becomes a psychological problem. No British sailor will for long serve blindly a remote computer with accurate data. His returns he will soon be treating with contempt. There is a need for a persuader. This is provided by making the returns first serve a useful purpose in the planning and control of work in the ship itself. Trials are at present under way in four Leander class frigates to this end, whereby the senior ratings effect controlled management of their groups of men by formal procedures which are subsequently used for SUIS.

31. The last phase of system design is probably the easiest. Sizing of the computer and writing the necessary programs for it are skills now fairly well established. SUIS will reach this stage in 1971.

**Identification**

32. It would be largely useless to report an upkeep event unless it were related to:—

(a) A known material state, and

(b) established behaviour norms.

33. Even similar equipments differ. They may be made by different contractors; some details—like the position of holes in a flange, for example—may not have been precisely specified; there may have been no opportunity to adopt a particular modification; they may have been bought to different hands. In other words, their configuration may differ. Control of their configuration or, at least, recording it, is exceedingly important if correct replacement spares are to be provided from a remote source or if an upkeep event is to be correctly related to material.

There are many ways in which configuration control can be effected. Basically, however, each component must be identified by drawing, code or words, stored in some way and this information must be capable of rapid retrieval when required. Because of the magnitude of the task, a computer is probably inevitable.

34. Configuration control in this form is being adopted first in the Type 21 frigates (Vosper Thornycroft) and Type 42 frigate (Vickers).

35. It would be easy, using computer information systems, to sink our fleet with paper. Wherever possible, therefore—and in SUIS it is extensively possible—reporting is by exception. This means that an upkeep event is reported only when behaviour is outside of tolerance boundaries. For example, if repair of an electric motor is expected to take ten weeks, it would be reported only if it took, say, less than nine weeks or more than 12. Furthermore, proper behaviour must be defined clearly for the operator so that he knows when "failure" has occurred. Subjective judgement is not good enough.

36. Behaviour norms of this sort are not always easy to define. A 40 per cent corrosion of the outer bottom thickness is typical of the more straightforward issues. Pump outputs and motor speeds can be easily measured too, to determine whether they have dropped below acceptable limits. However, vibration, gland leaks, cracks, dirt, appearance and distortion are rather more difficult to specify in terms of acceptable norms and subjective judgement will, in practice, always have a large part to play. Nevertheless, we must continue to specify what we expect of our ships in terms of their behaviour if we are to receive objective information from sea.

**Reliability engineering**

37. Our industry is one which has not yet fully appreciated the importance of reliability engineering. Only two shipbuilders are known to be actively interested and only a handful of sub-contractors dabble half-heartedly. Even when there is an emotional desire for reliability, this minor science is often confused with quality control.

38. The point is, of course, that the only incentives that most producers have are:—

(a) Reduction of expenditure during the guarantee period.

(b) Maintenance of reputation for good work.

Too often, perhaps, (b) is neglected because it represents a very long term investment and failures are, in any case, thought to be easily obscured by technological argument. Furthermore, most contractors are hard put to scrape an acceptable dividend in the current or subsequent year, without worrying too much about a couple of years hence. I will return to this question of incentives presently. In the meantime let us examine where reliability fits into the scheme of whole life prediction, costing and optimisation.

39. If we refer back to Fig. 4 we can see that nothing can progress beyond design for capability without an assessment of reliability. We cannot assess what degree of maintenance will be required, and when and where it should be provided; we cannot assess how available our product will be to the customer nor how many spares should be ordered; we cannot assess the total costs that our customer is committing himself to by our design and are therefore unable to recommend that which is the best for its whole life. The same can be seen from Fig. 5 in which action number 3 must be performed before 11, 16 and 24 can be performed and these in turn before 2, 12, 20, 28 and so on.

40. Not only must the breakdown pattern be predicted, but it must be predicted in quantitative terms. Engineers of all persuasions find it very difficult to take an objective view of failure; because of their inquiring minds and sense of personal responsibility, they feel that they must identify "failure" and attribute a cause. Where failure is expensive or potentially catastrophic this is, of course, right and proper. However, the vast majority of failures are not spectacular and the attribution of a cause is not at all profitable. The cause is simply some unlucky excess of stress—perchance a spot of dust at an electrical contact, cocoa spilt in the middle watch, a fragment slipped through the oil filter, inter-crystalline corrosion at a stress concentration, a drop of salt water at a crucial spot, acceleration forces in a seaway augmenting a normal loading, a bump in the night. Fig. 7 from Ref. 1 shows some of the environmental factors for which a marine designer may have to account. Were he to presume that the maximum of each of these factors occurred simultaneously, he would design a sledgehammer to crack a nut. He takes the reasonable view that the chances of such superposition are small and he designs to the environmental stresses (at least, those that can be defined at all) each separately. By so doing he is accepting chances of failure occurring, however small.

41. This argument suggests that the laws of chance will be suitable for predicting failure patterns and these form the theoretical aspects of reliability engineering. Books (e.g. Refs. 8, 9, 10) now abound in the subject. Basically, it is assumed that the numbers of failures which occur in equal intervals of time throughout the useful life of an article will follow

| | POSSIBLE ENVIRONMENTAL FACTORS | |
|---|---|---|
| CAUSES | All equipment | Additional for exposed equipment |
| Mechanical and electrical | Ship motion<br>Ship flexure<br>Pressure, high and low<br>Vibration slamming<br>Noise<br>Underwater shock<br>Bumping, dropping<br>Electrical supply fluctuation<br>Artificial light<br>Electro-magnetic radiation<br>Sparks, static electricity<br>Gyroscopic effects<br>Static inclination | Wave impact<br>Gun blast<br>Guided wepon efflux<br>Nuclear overpressure<br>Fendering<br>Radar infra red or underwater signatures |
| Climatic | Salt laden atmosphere<br>Condensation<br>Dust, fluff<br>Temperature extremes<br>Humidity extremes<br>Odour, aerosols | Wind<br>Green seas<br>Salt spray<br>Hail<br>Rain<br>Blown snow<br>Ice accretion<br>Sea ice<br>Total immersion<br>Sunlight<br>Funnel smoke<br>Sand abrasion |
| Others | Corrosive conditions<br>Oil contamination<br>Animal life<br>Mould<br>Nuclear radiation<br>Installation route<br>Maintenance access<br>Inexpert handling<br>Human mischief | Fish<br>Crustaceans<br>Sea weed<br>Flotsam<br>Sea bottom<br>Hydrography<br>Port facilities<br>Chemical attack<br>Bacteriological attack |

FIG. 7

some mathematically definable pattern. The most common of these frequency distributions is the exponential, in which the probability of failure not occurring in a time $t$, is given by $R(t)=e^{-\lambda t}$ where $\lambda$ is a constant called the failure rate. This distribution is applicable to the very large number of cases in which the chances of stress exceeding strength are entirely random.

42. In order to demonstrate the usefulness of this technique, let us examine a particular and topical example. Suppose an owner wishes to propel his fleet of five ships by gas turbine, two to each ship. Experience in the aircraft field indicates a randomness in the timing of failures with a mean failure rate of the gas turbines of once per 3,000 hours running. In each 30-day voyage the probability of there being no failure of each engine is $R\ (720\ \text{hours})=e^{-\frac{720}{3000}}=0{\cdot}79$

Thus, there is a one-in-five chance of each engine breaking down and a 0·38 chance that one or the other or both will fail on each voyage. Thus perturbed, the owner will at once decide that it would be wise to carry spare engines (since gas turbines are too delicate to repair at sea). How many should he carry? A more general form of the exponential distribution is the Poisson, which gives the probability of exactly $k$ failures occurring as:—

$$p(k)=\frac{(\lambda t)^k e^{-\lambda t}}{k\ !}$$

For each engine this gives:—

$p(0)=0{\cdot}79$
$p(1)=0{\cdot}19$
$p(2)=0{\cdot}02$
$p(3)=0$

Combining these in the manner shown at Appendix, we can deduce a curve (Fig. 8) showing the probability of the ship suffering one, two or three failures per voyage. This shows that there is a 0·07 chance of two failures and 0·01 chance of three failures every voyage. In other words, in ten voyages one of them will suffer two random gas turbine failures and four of them failure of some sort. Clearly such considerations are vital in the choice of machinery arrangement as well as the actual number of spares carried. They also profoundly affect the economics of using gas turbines.

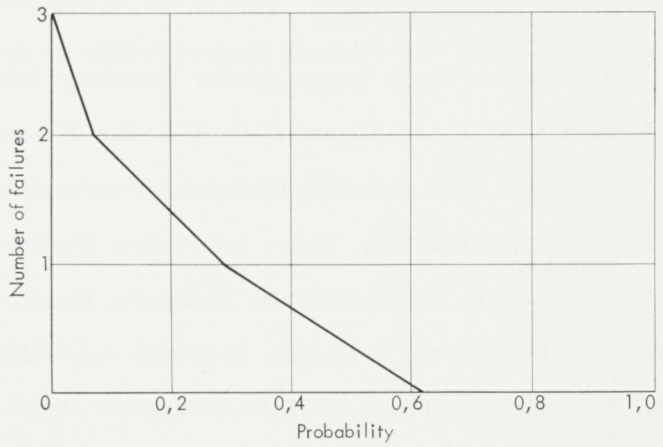


FIG. 8

43. Let us take the investigation a step further by examining one aspect of the economics of the choice (other aspects are given in Ref. 11). Supposing this owner ran five such ships. How many spare gas turbines should he buy presuming that they took six months to repair? Since they cost about £160,000 each his problem is an expensive one.

44. Using this time the cumulative Poisson distribution, the probability of $k$ or fewer failures is given by

$$p\ (\leqslant k)=\sum_{i=0}^{k}\frac{(\lambda t)^i e^{-\lambda t}}{i\ !}$$

Calculations are shown in the appendix. Obviously, the fewer the spares available the cheaper is the support; on the other hand, there is a higher risk of loss of earnings due to lack of spares. Fig. 9 shows the result, the top curve being the total amount that the owner is out of pocket. He would almost certainly choose the minimum of this curve. This represents a risk of about 20 per cent that he will be caught out of stock. He will stock 15 spares (valued at £2¼m) and probably decide to carry two of these in each ship.

45. This example is, of course, over-simplified but it is not wholly unreasonable. There will, for example, be fluctuations also to account for and there is mathematics of queueing to serve those (Ref. 12). The example is one of very many areas where reliability engineering can introduce a necessary numeracy into considerations of cost-effectiveness, cost-benefit, value engineering or decision theory.

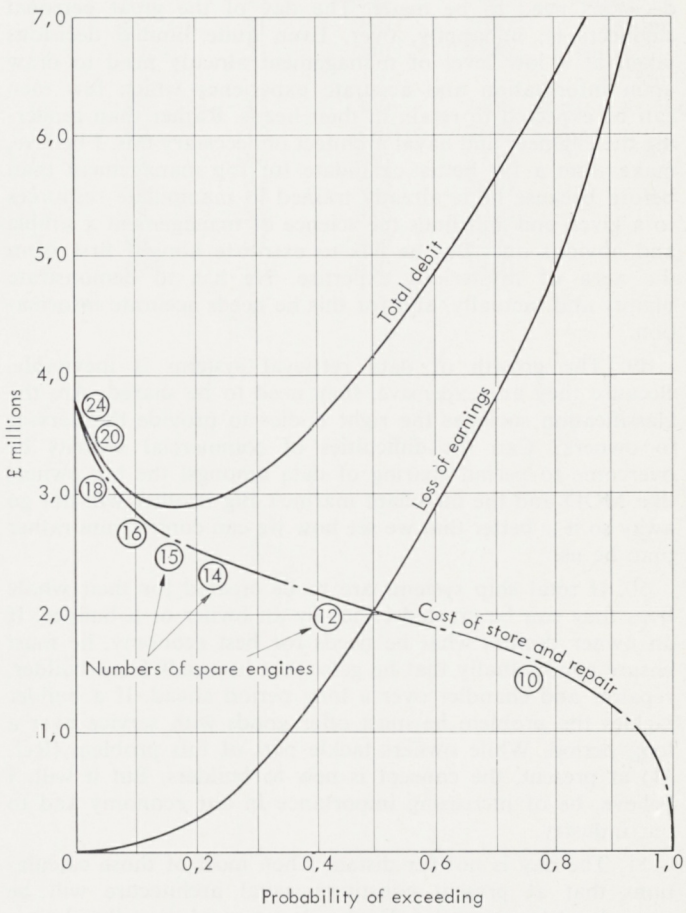


FIG. 9

**Quality assurance**

46. Quality control is only a means to an end. The end is not quality, whatever that may be, but that quality called reliability. It is a necessary, if imprecise, method of achieving reliability. The blanket approach of quality control was probably inspired by the hygiene of the operating theatre where the entire environment is controlled with a view to avoiding specific attack at the incision point. There is no doubt that the quality control forced upon a reluctant shipbuilding industry by the Ministry of Defence (Ref. 13) has brought great benefits. What is not so clear is whether the financial benefits derived therefrom have exceeded the cost of the measures themselves. The enthusiasts will argue strenuously that they have, but there is yet little firm evidence either way.

47. If reliability is the end, then the owner is entitled to receive some demonstration that it has been achieved by the contractor. Even using statistical sampling and such rapidly converging techniques as Bayesian statistics, it is often an expensive affair. Nevertheless, by judicious choice of equipment and firm, large benefits can accrue; the firm faced with the results of its own efforts and the owner confident that he can begin operations economically.

**The future**

48. Whether we like it or not, we are entering an age in which personal experience will not be sufficient when costly decisions need to be made. The day of the great personal engineers is, unhappily, over. Even quite limited decisions taken at a low level of management already need to draw upon information and accurate experience which few men can be expected to retain in their heads. Rather than rendering the engineer and naval architect unnecessary this, I believe, makes him a far better candidate for top management than before because he is already trained to manipulate resources to a given end and finds the science of management a simple and obvious one. But he has to extricate himself first from the aura of mysterious expertise. He has to demonstrate plainly and factually, and for this he needs accurate information.

49. The growth of data retrieval systems is inevitable. Because they are expensive, they need to be shared. Are the classification societies the right bodies to provide this service to owners? Can the difficulties of commercial security be overcome to permit sharing of data amongst the big owners like MOD and the merchant marine? Big Brother will not go away so it is better that we see how we can control him rather than he us.

50. If total ship systems are to be created for their whole lives they can be created either by an owner or a builder. If an owner decides what he needs for best economy, he must ensure contractually that he gets what he needs from builder, repairer and chandler over a long period ahead. If a builder tackles the problem he must offer goods with service over a long period. While owners tackle part of this problem (Ref. 11) at present, the concept is new to builders. But it will, I believe, be of increasing importance in our economy and to our industry.

51. The day is not far distant when most of those calculations that at present constitute naval architecure will be carried out by computer. Form selection and propeller design, ship dynamics, ship strength, ship measurement, vulnerability and stability are all more or less reducible to some methodical selection and manipulation. During the next few years we must expect a gradual transition in this respect, aided by a continuing high level of investment in post graduate research. Thus, much of the traditional naval architect's bread and butter work will disappear.

Far from depriving him of work, this does, I believe, provide him with the opportunity to synthesize the whole ship system on the basis of whole life economy. This has never been fully exploited. Instead of being too involved with the design to worry too much about operation and maintenance, he can look at the whole picture and design deliberately to specific methods of operation maintenance and logistics. He can consider diverse ways of operating to optimise profit without being pre-empted from the outset by a requirement stated in terms of ship size, machinery choice and convention. He can range over such solutions as button-on sterns, the LASH concept or other mixtures of craft and size without facing the mammoth task of conventional ship design before each idea is evaluated. Some of the solutions would undoubtedly involve irregular survey or proscription of the Classification Society rules and therefore their co-operation from the outset.

52. Systems engineering, as I have discussed it in this paper, involves a wide ranging knowledge over many subjects. It is indistinguishable from operational research or value analysis and it uses tools borrowed from many sciences. Naval architects, I believe, have a natural aptitude for it but they are not exclusive candidates. They need to diversify into many fields, but mostly into economics. It is, after all, the day of the economist.

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# APPENDIX

## RELIABILITY ENGINEERING EXERCISE

**Assumptions**

1. Five ships at sea, two engines driving each.
2. Five voyages in six months, each voyage being 30 days long.
3. Repair time of engine is six months.
4. Failure rate of engine $\frac{1}{3000}$ per hour. Exponential density function.
5. Engine cost £160,000. Repair cost £20,000.

How many failures in each ship, each voyage?

By Poisson distribution for each engine

$$p\ (0)=e^{-\lambda t}=\cdot 79$$

$$p\ (1)=\lambda t\ e^{-\lambda t}=\cdot 19$$

$$p\ (2)=\left(\frac{\lambda t}{2!}\right)^2 e^{-\lambda t}=\cdot 02$$

$$p\ (3)=\left(\frac{\lambda t}{3!}\right)^3 e^{-\lambda t}=0$$

For each ship with engines A and B.

Probability that both A and B survive $=p\ (0)=(0\cdot 79)^2=0\cdot 62$

Probability of one failure $=p$ (one A) (no B) $+$ $p$ (no A) (one B)

i.e. $p\ (1)=2\times 0\cdot 19\times 0\cdot 79=0\cdot 30$

Probability of two failures $=p$ (one A) (two B) $+$ p (no A) (two B) $+$ $p$ (one A) (one B)

i.e. $p\ (2)=2\times 0\cdot 02\times 0\cdot 79+(0\cdot 19)^2=\cdot 07$

Probability of three failures $=p$ (one A) (two B) $+$ $p$ (two A) (one B)

i.e. $p\ (3)=2\times 0\cdot 19\times 0\cdot 02=0\cdot 01$

How many failures will occur in six months when the repair cycle is complete?

Total running hours $=36000$ hours; $e^{-\frac{36000}{3000}}=e^{-12}$

Using a Thorndike cumulative Poisson chart:—

| Number of failures $n$ (stock level) | $p(\leqslant n)$ | $p(\geqslant n)$ | Cost of repair £$k$ | Cost of stock £$k$ | Loss of earnings |
|---|---|---|---|---|---|
| 0 | 0 | 1 | 0 | | |
| 1 | 0 | 1 | 30 | 160 | |
| 2 | ·001 | ·999 | 40 | 320 | |
| 3 | ·0012 | ·999 | 60 | 480 | 5 ships= |
| 4 | ·01 | ·99 | 80 | 640 | £7·5m |
| 5 | ·011 | ·989 | 100 | 800 | |
| 6 | ·04 | ·96 | 120 | 960 | |
| 7 | ·09 | ·91 | 140 | 1120 | 4 ships= |
| 8 | ·15 | ·85 | 160 | 1280 | £6·0m |
| 9 | ·24 | ·76 | 180 | 1440 | |
| 10 | ·35 | ·65 | 200 | 1600 | 3 ships= |
| 11 | ·46 | ·54 | 220 | 1760 | £4·5m |
| 12 | ·57 | ·43 | 240 | 1920 | 2 ships= |
| 13 | ·69 | ·31 | 260 | 2080 | £3·0m |
| 14 | ·77 | ·23 | 280 | 2240 | 1 ship= |
| | | | | | £1·5m |
| 15 | ·85 | ·15 | 300 | 2400 | some restriction |
| 16 | ·90 | ·10 | 320 | 2560 | none |
| 17 | ·94 | ·06 | 340 | 2720 | |
| 18 | ·96 | ·04 | 360 | 2880 | |
| 19 | ·98 | ·02 | 380 | 3040 | |
| 20 | ·99 | ·01 | 400 | 3200 | |
| 24 | ·999 | ·001 | 480 | 3840 | |

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# THE SURVEY OF SAFETY EQUIPMENT ON CARGO SHIPS

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# THE SURVEY OF SAFETY EQUIPMENT ON CARGO SHIPS

by G. SMART

## PART I

### INTRODUCTION

Since Mr. Macmillan presented his classic paper, "The Survey of Safety Equipment", 13 years ago, the Society's role in this field has widened considerably and the advent of the 1960 International Convention for the Safety of Life at Sea brought about many changes with a view to improving safety measures in ships.

The need for up-to-date information on this subject is, therefore, obvious and, whilst the Inter-Government Maritime Consultative Organisation has the matter under constant review and various new amendments are adopted by different Governments from time to time, it is felt that the Society's Surveyors need to be acquainted with the latest developments, hence the reason for this paper.

Safety Equipment Surveys have formed part of the Society's activities since 1953 and there are now quite a number of colleagues who have considerable experience of the work on both new and existing ships, together with an intimate knowledge of the Regulations: on the other hand there are many, and particularly at the smaller ports throughout the world, who have had little opportunity to familiarise themselves with these inspections and find difficulty in adopting the role of a Surveyor acting on behalf of a National Authority and applying the relevant regulations. It is to these latter colleagues that this paper is primarily directed, but it is felt that the more experienced, whilst viewing the details with a tolerant eye, will also welcome the latest information contained herein.

Certain countries, having accepted the 1960 Convention, have introduced their own National Regulations which are more rigorous in some respects than the Convention Regulations, whilst other countries have not done so. Furthermore, as with the 1948 Convention Regulations, the present Convention Regulations are not altogether specific in some respects, whilst in others varying interpretations are possible as the application of certain requirements has been left to the discretion of the Administration concerned. This, unfortunately, brings about an inevitable lack of uniformity of practice between maritime countries and the existence of these discrepancies is not always fully appreciated by many Shipowners who wrongly assume that the Regulations and their application are consistent throughout the world and what applies to one ship, also applies to another, irrespective of the country in which it is registered.

The Shipowners' unawareness in this respect has come to light in many instances and often occurs when a ship changes flag after purchase and the Owner, knowing full well that a Safety Equipment Certificate was issued under the provisions of the International Convention for the Safety of Life at Sea, 1960, by the Administration of the country of previous registration, becomes somewhat perturbed when faced with the expense and inconvenience of providing additional equipment in order to obtain a similar document, issued under the provisions of the same Convention, but on behalf of the Government of the country of new registration. These facts should be borne in mind when a ship changes flag and the Society has not previously issued the Safety Equipment Certificate.

This paper sets out to define those requirements which the Convention Regulations leave unspecified and seeks to convey the particular requirements of the countries on whose behalf the Society is authorised to act.

#### General Procedure

Safety Equipment and Radiotelegraphy Surveys are to be dealt with *only* by the Society's Exclusive Surveyors. Occasions may arise where Non-Exclusive Surveyors, Acting Surveyors, or even the Society's Agents at certain ports may be called upon to intervene in special circumstances, but authorisation from London Office is necessary in these cases. This should be made clear to Owners and Masters as the opportunity arises. Furthermore, these inspections are to be carried out and certificates issued on the Society's form *only* in cases where the Government concerned has authorised the Society or the Surveyor to do so. If any doubt exists instructions should be sought from London Office.

Safety Equipment and Radiotelegraphy Surveys and Certificates do not apply to passenger ships. Requests for surveys in connection with the issue of Passenger Ship Safety Certificates should be referred to London Office.

#### Classification and the International Regulations

It is thought well at this stage to point out that Safety Equipment Surveys are quite independent of surveys for Classification and the requirements are laid down, not by the Society, but by the Government of the country in which the ship is registered.

It must be borne in mind, however, that the fire protection, detection and extinction arrangements and their inspections are also Classification requirements, therefore, in new ships building to class and existing ships being classed for the first time by the Society, plans of the fire protection, detection and extinction arrangements are to be submitted for approval. Subsequent Surveys carried out by, or on behalf of the National Authority of the country in which the ship is registered may be accepted as meeting the Society's Classification Survey requirements.

For Classification purposes, therefore, the date of expiry of the Safety Equipment Certificate with the name of the issuing authority is to be indicated in the Rpt. 1 for new ships and in the Rpt. 8 at each regular drydocking in the case of existing ships, as stated in Instructions to Surveyors, Part 3a 1963, Amendments No. 6 and No. 13.

When carrying out a Safety Equipment Survey and the repair or replacement of defective or deficient fire equipment is deferred, it naturally follows that the Classification of the ship is also affected and, in addition to the Safety Equipment reporting procedure, it is necessary to forward a Rpt. 8 detailing the outstanding items which become Conditions of Class and issue the relevant Interim Certificate.

## The International Regulations for the Safety of Life at Sea

In the early hours of the 15th April, 1912, the White Star passenger liner *Titanic,* at that time the largest ship afloat, struck an iceberg in the North Atlantic and subsequently sank with the loss of more than 1,500 lives. This disaster stimulated international interest in safety at sea and led to the first International Conference on Safety of Life at Sea. During the winter of 1913–14, at the invitation of the United Kingdom, delegates representing major maritime countries met in London and the deliberations resulted in the first International Convention for the Safety of Life at Sea.

The Convention was not, however, put into effect due to the outbreak of war in 1914, but many countries adopted some of its terms which were used as a basis for future conventions.

In 1929 the second International Conference was convened and delegates representing 18 of the world's maritime countries met in London, and agreed to a Convention which was put into effect. The Convention, which was acceded to by 36 countries, concerned itself chiefly with safety measures in passenger ships and introduced requirements for cargo ship radio installations.

In 1948 the third International Conference on Safety of Life at Sea met in London. Delegates of 30 countries attended and agreed to a new Convention to replace that of 1929. The 1948 Convention came into force on the 19th November, 1952, and brought about more detailed requirements for cargo ships. By 1959 52 countries had agreed to make it effective.

At this stage the Inter-Governmental Maritime Organisation was formed for the purpose of dealing with technical and legal matters concerning international shipping. I.M.C.O. is a specialised agency of the United Nations and its principal objects on the technical side are to facilitate co-operation among governments, to co-ordinate regulations, to make recommendations to governments and to establish codes of practice.

In 1960, at the invitation of I.M.C.O., another International Conference on Safety of Life at Sea was held in London. Forty-five countries sent delegations and ten countries sent observers. The purpose of this Conference was to draw up and agree to a new Convention to replace that of 1948, which it further extended, bringing the detailed requirements into line with latest developments. The deliberations resulted in the International Convention for the Safety of Life at Sea, 1960, which came into force on the 26th May, 1965, following its acceptance by not less than 15 countries, including seven countries each with a minimum of one million tons gross of shipping and, since that date, further acceptances bring the total at the time of writing to 79 countries.

## Authorisation

The status in respect of the International Convention for the Safety of Life at Sea, 1960, and the countries which have authorised the Society to carry out inspections and surveys on their behalf are indicated in the following list. A complete register of major maritime countries is given in order to enable any future authorisation and amendments to be noted thereon and thus keep the record up-to-date.

The acceptance of the 1960 Convention is shown in Column 1 by the date when it came into effect for the country concerned.

| Country | 1 SOLAS 1960 | 2 L.R. AUTH. |
|---|---|---|
| ALGERIA | 26.5.65 | SCU |
| ARGENTINE | 27.7.66 | |
| AUSTRALIA | 20.3.68 | |
| BAHAMAS† | | |
| BELGIUM | 10.4.66 | |
| BERMUDA† | | |
| BRAZIL | 8.6.67 | SCU |
| BULGARIA | 16.1.68 | |
| BURMA | 12.10.65 | |
| BURUNDI | | SCU |
| CANADA | 26.5.65 | |
| CAYMAN ISLANDS | | SCU |
| CHILE | 7.12.66 | |
| CHINA (TAIWAN) | 26.5.65 | |
| COLOMBIA | | |
| CONGO (BRAZZAVILLE) | | |
| CONGO (KINSHASA) | 20.8.68 | SCU |
| CUBA | 26.5.65 | SCA |
| CYPRUS | 26.10.65 | SCU |
| CZECHOSLOVAKIA | 5.10.67 | |
| DENMARK | 26.5.65 | |
| ETHIOPIA | | SCU |
| FINLAND | 26.5.65 | |
| FRANCE | 26.5.65 | |
| GERMANY (FED. REP.) | 26.5.65 | |
| GHANA | 26.5.65 | SCU |
| GIBRALTAR† | | |
| GREECE† | 26.5.65 | SCU |
| GUINEA | 5.12.68 | |
| HAITI | 26.5.65 | SCU |
| HONDURAS | 18.5.69 | SCU |
| HONG KONG | 7.12.65 | |
| ICELAND | 26.5.65 | |
| INDIA | 28.5.66 | |
| INDONESIA | 26.1.67 | |
| IRAN | 31.8.66 | SCU |
| IRAQ | | |
| IRISH REPUBLIC | 14.5.67 | |
| ISRAEL† | 5.1.66* | SCA |
| ITALY | 26.8.66 | |
| IVORY COAST | 2.2.66 | |
| JAMAICA | 22.5.68 | |
| JAPAN | 26.5.65 | |
| KENYA | | SCU |
| KOREA (SOUTH) | 26.5.65 | |
| KUWAIT | 26.5.65 | SCU |
| LEBANON† | 27.7.66 | SCU |
| LIBERIA† | 26.5.65 | SCU |
| MALAGASY REP. | 26.5.65 | |
| MALAYSIA | 16.11.65 | SCU |
| MALDIVE ISLANDS | 29.4.68 | SCU |
| MALTA† | | |
| MAURITANIA | 4.3.68 | |
| MEXICO | 22.9.66 | SCU |
| MOROCCO | 26.5.65 | |
| NAURU | 18.4.70 | SCU |
| NETHERLANDS† | 26.5.65 | SO |
| NEW ZEALAND | 14.4.66 | |
| NICARAGUA | 9.1.68 | SCU |
| NIGERIA | 28.2.66 | |
| NORWAY† | 26.5.65 | SO |
| PAKISTAN | 24.5.66 | |
| PANAMA | 12.1.66 | SCU |
| PAPUA & NEW GUINEA | | |
| PARAGUAY | 26.5.65 | |
| PERU | 26.5.65 | |
| PHILIPPINES† | 11.11.65 | SO |
| POLAND | 29.7.66 | |
| PORTUGAL | 14.9.66 | |
| ROMANIA | 12.3.67 | |
| SABAH | 16.11.65 | SCU |
| SARAWAK | 16.11.65 | SCU |
| SAUDI ARABIA | 26.5.65 | |
| SINGAPORE | 12.5.69 | SCU |
| SOMALIA | 30.6.67 | SCU |
| SOUTH AFRICA | 13.6.68 | |
| SOUTHERN YEMEN | 20.8.69 | |
| SPAIN | 26.5.65 | |
| SWEDEN† | 23.3.66 | SO |
| SWITZERLAND | 12.4.66 | SCU |
| TANZANIA | | SCU |
| TRINIDAD & TOBAGO | 6.12.66 | SCU |
| TUNISIA | 26.5.65 | |
| TURKEY | 2.9.66 | |
| UGANDA | | SCU |
| UNITED ARAB REP. | 27.10.65 | |
| UNITED KINGDOM† | 26.5.65 | |
| U.S.A. | 26.5.65 | |
| U.S.S.R. | 4.11.65 | |
| URUGUAY | 19.12.68 | |
| VENEZUELA | 23.4.69 | |
| VIETNAM (SOUTH) | 26.5.65 | |
| YUGOSLAVIA† | 26.5.65 | SCA |

* Israel adopted the 1960 Convention for new ships laid down on or after 1.1.62.

† Special instructions apply to ships registered in these countries.

The extent to which the Society is authorised to act on behalf of a Government is shown in column 2 by the following symbols:—

SCU The Society is fully authorised and Surveyors may carry out Safety Equipment Surveys and issue the appropriate short-term certificates, when requested to do so, without reference to London Office.

SCA As for SCU, but applicable only to ships *outside the country in which they are registered.*

SO Surveys may be held *only* in special circumstances.

Special instructions apply to ships registered in countries marked thus † as follows:—

## BAHAMAS

Owners of ships registered in the Bahamas are required to make direct application to the Registrar of Shipping, Nassau, in each individual case, when they wish the Society's Surveyors to carry out a Survey and issue the appropriate Non-Convention Certificate. In order to expedite matters the Survey may be proceeded with at the Owners' request, but the certificate should not be issued until the letter or cable of authorisation has been produced. If instructions have not been issued from London Office, a copy of the communication from the Registrar of Shipping is to accompany the report.

## BERMUDA

The procedure is the same as for ships registered in the Bahamas except that the Registrar of Shipping, Hamilton, is the authority in this case.

## GIBRALTAR

The procedure is the same as for ships registered in the Bahamas, except that The Registrar of Shipping at Gibraltar is the authority in this case.

## GREECE

All reports (except the Rpt. SE1) and copies of documents issued are to be sent to London Office in *duplicate*. This is to enable one copy to be sent to Piræus for retention in the files of the Greek Inspectorate of Merchant Vessels.

## ISRAEL

In accordance with the agreement signed between the Israeli Ministry of Transport (I.M.O.T.) and the Society, the Surveyors are required to undertake the statutory and associated surveys on Israeli ships in ports outside Israel and, as an extraordinary procedure is entailed, details are given as follows:—

1. The surveys to be carried out are renewal surveys viz.:—

(a) Surveys for the issue of certificates in accordance with the provisions of the International Convention for the Safety of Life at Sea, namely: Passenger Ship Safety Certificates only to ships classed with the Society, Cargo Ship Safety Equipment, Radiotelegraphy and Radiotelephony Certificates to ships classed with the Society or other Classification Societies. All Certificates issued to Israeli ships are valid for periods not exceeding 12 months.

(b) Surveys of crew accommodation and sanitation arrangements, also of other deck and engine items as required for the issue of the National Navigation Licence by the I.M.O.T.

2. The Rules and Regulations to be used are:—

(a) The 1960 S.O.L.A.S. Convention requirements which are applicable to all new ships the keel of which was laid after the 1st January, 1962.

(b) The 1948 S.O.L.A.S. Convention applicable to all existing ships.

(c) The I.M.O.T. Crew Accommodation Regulations, identical with the U.K. Merchant Shipping (Crew Accommodation) Regulations, as amended in December 1954.

(d) The I.M.O.T. Medical Regulations.

3. Procedure

A letter of request for survey will be sent by the I.M.O.T. to the Surveyors concerned stating the port and expected date of arrival of the ship and other particulars, together with a set of coloured survey booklets in respect of the surveys to be carried out. There are five such booklets, each listing the items to be reported upon under the following headings:—

DECK BOOK (GREY)

Documents, Lifesaving appliances, Bridge and chart room equipment, Lights and shapes, Fire fighting arrangements, Miscellaneous equipment.

ANNEX TO DECK (GREY)

Survey of Crew Accommodation.

HEALTH SURVEY (YELLOW)

Documents, Medicine Chest, Ship's hospital, Dispensary (passenger ships only), Drinking and seawater supplies, Waste disposal, Laundry, Food sanitation, Hairdressers, etc., Domestic services and General hygiene.

RADIO (GREEN)

Documents, Plans and publications, Radio Officers, Radio station equipment, Aerials, Power supplies, Transmitters, Lifeboat transceiver, Receivers and other equipment, Navigational aids, Frequencies provided and Transmitter tests.

ENGINE (ORANGE)

Documents, Class records, W.T. doors, Bilge pumping system, Boilers and pressure vessels, Main engines and auxiliaries, Electrical equipment and compressors, Fuel tanks and firefighting.

It will be observed from the foregoing that the inspection and reporting involved is more onerous than that required for a normal Safety Equipment Survey and the examination of certain items is beyond the Surveyors' capabilities. It is, therefore, necessary to employ the services of skilled personnel to survey any special equipment with which the Surveyor is unacquainted.

The Health Survey includes verifying that the contents of the medicine chest comply with the requirements laid down in "Regulations, List of Medicines and Instruments for Israeli Merchant and Fishing Vessels" pages 52–57), a copy of which is retained on board each ship. A Pharmacist should be appointed to carry out this inspection and issue a statement of his findings. Similarly, the survey of the Radio Installation should be dealt with by an expert, as should nautical equipment such as compasses, chronometer, etc.

4. Special Requirements

Attention is drawn to the following specific requirements of the Israeli Ministry of Transport: —

(a) Lifeboat provisions.

Every lifeboat is to be provided with not less than the rations given below for each person the boat is certified to carry: —

(i) 3 litres of fresh water, the quantity to be increased as far as practicable.

(ii) 1 kg of approved provisions.

(iii) ½ kg condensed milk of first quality.

The provisions under (ii) above can consist of: —

(a) 1 kg biscuits, or

(b) ½ kg biscuits and ½ kg boiled sweets, or

(c) 1 kg lifeboat rations which are approved by a country which has accepted the 1960 S.O.L.A.S. Convention, i.e. Scandinavian and Dutch rations. Corned beef, salted beef or other thirst producing food is not permitted.

The milk (iii) above may be either condensed or evaporated.

(b) Pyrotechnic Signals.

In addition to the distress signals required by the International Regulations, at least six "blue lights" are to be carried for the purpose of attracting attention as permitted in Rule 12 of the International Collision Regulations.

5. Booklets, Certificates and Reports

It is not necessary to use the Society's forms when reporting surveys of Safety Equipment and Radiotelegraphy installations, but it is essential that the items in each booklet be reported upon in the appropriate column, stating "Good" for condition and other remarks as required. Where any items mentioned are not provided or are not applicable, this should be stated.

It will be noted that the booklets are printed according to the National practice, therefore the first page is at the back. After dealing with the pages listing the various items, it will be found that each of the Deck, Health, Radio and Engine booklets contains several pages headed "Survey Declaration" with alternate pages perforated for removal. The Declaration is to be made out in the case of each partial or complete survey, and written in duplicate using carbon paper if available, the perforated page being removed and handed to the Master.

When any survey is incomplete the Declaration is to detail the outstanding items and the booklets left with the Master who should be requested to hand them to the Surveyor at the next survey port. This procedure is to be repeated until the inspection has been completed in its entirety.

(a) Passenger Ships

On completion of the survey for the renewal of the Passenger Ship Safety Certificate the Surveyor is to issue a statement on the Society's form Rpt. 10 that he has surveyed the ship and found the arrangements in satisfactory condition and in agreement with the survey booklets.

A copy should be sent to London Office. A copy should also be sent to the Israeli Ministry of Transport in Haifa together with the completed booklets.

Passenger Ship Safety Certificates are issued by the I.M.O.T. and not by the Society.

(b) Cargo Ships

On completion of the surveys for the renewal of the Safety Equipment and Radiotelegraphy Certificates the Surveyor is to issue short-term certificates on the Society's forms SEST and SRST valid for six months sending a copy of each to London Office together with the survey booklets.

Copies of all short-term certificates issued and the previous certificates are to be sent direct to the I.M.O.T. Haifa.

In the case of all ships where the survey has not been completed, a Rpt. 10 only is to be issued detailing the outstanding items. If it is known where the survey is to be completed, a copy of the Rpt. 10 and an explanatory letter should be sent to the Surveyors concerned. Copies of the Rpt. 10 and relevant correspondence are to be sent to the I.M.O.T. Haifa and to London Office.

Where the surveys of Safety Equipment and Radiotelegraph Installation have been completed but the Crew Accommodation and Sanitation Surveys are incomplete, this will not prevent the issue of the Certificates SEST and SRST, but a Rpt. 10 will also be required detailing the items not dealt with.

If the vessel or its equipment is found to be deficient to such an extent that the ship is unfit to proceed to sea, the Israeli Ministry of Transport should be informed immediately by cablegram or telex, cable address "MEMSAPANUT, HAIFA", Telex No. 632, giving details of the deficiency and requesting instructions.

Except where a survey has already been commenced at another port, if a request for the survey of an Israeli ship is received from the Owners, Master or any source other than the Israeli Ministry of Transport or London Office and the relevant booklets are not available, a cablegram should be sent to the I.M.O.T., Haifa, requesting instructions.

6. Fees

Accounts in respect of fees and expenses for these surveys are not to be rendered to Owners or Agents by Outport Offices. A Fee Request letter, obtainable from the Printing House, if not already in use, should be completed and sent to London for the attention of the Chief Accountant to enable the appropriate amount to be recovered by London Office concordant with the I.M.O.T./L.R. agreement.

In addition to the fees for the Safety Equipment and Radiotelegraphy Surveys in accordance with the Society's Scale of Fees, a fee commensurate with services rendered, is chargeable for the other further work involved. Moreover, all fees paid to specialists such as the Pharmacist are to be detailed, together with expenses incurred.

## LEBANON

Full Term Safety Equipment and Radiotelegraphy Certifiare issued, not by the Society, but by the Lebanese Authorities. All reports (except the Rpt. SE1) and Certificate copies are to be sent to London Office in *duplicate*.

## LIBERIA

Five copies of all short-term certificates issued by the Surveyors to Liberian ships are to be sent direct to the Society's New York Office for transmission to the Liberian Bureau of Maritime Affairs.

The Liberian Authorities attach great importance to all appropriate documents being issued to a Liberian ship before

leaving port, particularly when a ship transfers to Liberian Registry from registries of other countries.

Whilst the majority of Administrations accept Certificates issued by another Government in accordance with Regulation 13, Chapter 1 of the 1960 S.O.L.A.S. Convention, it should be noted that the Liberian Authorities do not recognise this Regulation and will only accept certificates issued by the five Classification Societies which are their appointed authorised agents namely, American Bureau of Shipping, Bureau Veritas, Det Norske Veritas, Germanischer Lloyd and Lloyd's Register of Shipping. Furthermore, Liberian Consuls are not empowered to endorse or accept certificates issued by another Government, nor to extend the validity of certificates on board a Liberian ship.

When a ship transfers to Liberian registry and the Society has not previously issued the Safety Equipment Certificate, it is therefore essential that the Safety Equipment Survey be dealt with in its entirety and a complete Rpt. SE1 prepared. It is of equal importance that, in addition to Safety Equipment, all relevant Surveys for the issue of Liberian Loadline, Radiotelegraphy or Radiotelephony and Tonnage Certificates also be dealt with as registration formalities cannot be finalised until full term documents have been issued and these facts should be made clear to the Owners at the outset.

## MALTA

The procedure is the same as for ships registered in the Bahamas except that the Registrar of Shipping, Valetta, is the authority in this case. If considered necessary, the Malta Surveyors may be cabled requesting assistance in securing the required authorisation.

## NETHERLANDS

The Society is not authorised to carry out Safety Equipment or Radiotelegraphy Surveys or issue Certificates to ships over 500 tons gross registered in Holland.

Whilst ships of under 500 tons gross are exempt from the S.O.L.A.S. Convention requirements, those registered in Holland are required to comply with the National Regulations and undergo periodical survey and the Society's Surveyors are authorised to carry out these inspections in ports outside Holland, when requested to do so by the Netherlands Shipping Inspectorate, Agents or Master, who should provide the form "RECORD OF SAFETY EQUIPMENT" which requires to be completed and returned. No certificate is to be issued in these cases.

When carrying out these inspections the Surveyors' attention is drawn to the following specific requirements of the Netherlands Shipping Inspectorate: —

(a) Pyrotechnic distress signals are acceptable for a period of four years.
(b) A portable radio apparatus for use in survival craft is not required.
(c) A line-throwing apparatus is not required.
(d) See Annex I for details of life-saving and fire appliances required by the Dutch National Authorities.

## NORWAY

In accordance with an agreement with the Norwegian Maritime Inspectorate, the Society is authorised to carry out inspections on Norwegian ships classed with the Society, in countries outside Norway, for the issue of Cargo Ship Safety Equipment and Trading Certificates.

Such surveys are to be undertaken only by appointment on each individual occasion, from either the Norwegian Maritime Directorate, or the Norwegian Consular Office.

Only the special report forms, issued by the Norwegian Maritime Directorate are to be used, as follows: —

Form No. L3 (Translation) for the issue of Safety Equipment Certificates for Cargo Ship of 500 tons gross and over engaged on International Voyages.

Form No. L4 for the issue of a Trading Certificate for Cargo Ships of 500 tons gross and over. This report covers particulars of navigating instruments, protection of crew, inspection of crew accommodation, legal documeets, logbooks and medical supplies and manning details.

Form No. L5 for the issue of a Trading Certificate for Cargo Ships under 500 tons gross. This report covers the survey of accommodation and equipment for ships which are not issued with a Safety Equipment Certificate.

The relevant reports are to be completed and returned to the Norwegian Maritime Directorate or the Consulate as required in each individual case.

Fees commensurate with the nature and extent of the services rendered are to be charged to the Shipbuilder, Owner or Agent and a copy of the account is to be attached to the report sent to the Maritime Directorate.

The Society is *not* authorised to arrange Radiotelegraphy Surveys or issue Safety Equipment and Radiotelegraphy Certificates to Norwegian ships. Any request for the issue of such documents should be referred to the Norwegian Consul who is empowered to extend the validity of certificates for periods up to five months. The Surveyors have, on occasions, issued the Society's Certificates SEST and SRST to Norwegian ships at the request of the Consul, but the Norwegian Authorities do not approve of this practice. Under no circumstances, therefore, are Certs. SEST and SRST to be issued.

## PHILIPPINES

Where Safety Equipment and Radiotelegraphy Certificates require to be extended or renewed, the Shipowners normally refer the matter to the Philippine Coast Guard who in turn make representations through the Department of Foreign Affairs to request other Governments to conduct the surveys and issue the relevant certificates.

Circumstances may arise, however, where this procedure is impracticable and in these cases, the Philippine Authorities have authorised the Society to carry out the inspection of Philippine registered ships for the issue of certificates under the provisions of the 1960 S.O.L.A.S. Convention, in any foreign country whenever it is necessary.

The relevant reports must firstly be authenticated by the Philippine Consulate before being submitted to the Philippine Coast Guard Headquarters through the Manila Office, to enable full term certificates to be issued by the Authorities. Short-term certificates are not normally required as the Consul usually extends the validity of the current document when necessary.

## SWEDEN

The Society is not generally authorised to carry out Safety Equipment Surveys on Swedish ships, but the Swedish Board of Shipping and Navigation has agreed that such inspections

may be held by the Society's Surveyors in countries outside Sweden, when specifically requested to do so by the local Swedish Consul, in each individual occasion.

Only the special report forms, provided by the Consul, are to be used, namely: —

(1) REPORT of periodical Survey of Seaworthiness of a classed vessel.

(2) APPENDIX 2 INSPECTION concerning equipment, etc.

(3) APPENDIX 3 REPORT of inspection as to living quarters and other spaces for the use of the crew.

The forms, when completed, are to be returned to the Consul, together with a Cargo Ship Safety Equipment Report issued on a Rpt. 10 (see Annex II). This will enable the Consul to extend the validity of the existing Safety Equipment Certificate on board, pending the issue of a new document by the Swedish Authorities.

The Society's Certificate form Cert. SEST is *not* to be issued to a Swedish ship, nor are the Society's Report forms Rpt. SE1 and SE2 to be used.

## UNITED KINGDOM

Safety Equipment Surveys of ships registered in the United Kingdom may only be undertaken at the specific request of the Department of Trade & Industry when the Surveyor nominated will receive instructions and relevant forms from the D.T.I.

If a ship registered in the U.K. is in a country which has accepted the 1960 Convention and requires a survey for the renewal of the Safety Equipment Certificate, the Master or Agents should refer to the British Consul who should, in turn, request the Government Authorities to carry out the inspection and issue a certificate, in accordance with Regulation 13, Chapter I of the Convention. If the ship is in a country which is not a signatory to the Convention, British Consuls in non-Commonwealth countries and Shipping Masters in Commonwealth countries are empowered by the United Kingdom Merchant Shipping Acts to extend the validity of the certificate for a sufficient period (not exceeding five months) to enable the ship to proceed either to the United Kingdom or another Convention country, where the survey can be carried out and the appropriate Convention Certificate issued.

Surveyors must not undertake surveys at the request of British Consuls or Owners, and the Society's form Cert. SEST must not be issued under the authority of the Government of the United Kingdom and Northern Ireland. Where doubt exists, the case should be referred to London Office in order that the matter can be referred to the Department of Trade & Industry.

## YUGOSLAVIA

The agreement between the Society and the Jugoslav Register has recently been extended to include Statutory Surveys and the Society's Surveyors may now undertake periodical Safety Equipment, Radiotelegraphy and Radiotelephony Surveys outside the Socialist Federal Republic of Yugoslavia on existing Yugoslav ships classed with both Societies, at the request of the Owners or their accredited representatives.

The Society's Certificate forms are not to be issued in these cases but the Surveyor is to extend the validity of the respective JR Certificate for a period not exceeding five months upon satisfactory completion of the survey.

The Society's Surveyors may also undertake general or partial surveys outside Yugoslavia, upon request, for the purpose of recommending repairs or replacements whenever items of safety equipment are lost or damaged or when important repairs or renewals are being carried out. The Survey is to include examination to ensure that recommended repairs or renewals have been effectively made, that the materials and workmanship of such repairs or renewals are satisfactory and that the ship complies in all respects with the relevant Regulations. The testing and inspection during manufacture and installation outside Yugoslavia of materials and equipment intended for the repair of such ships are also to be dealt with by the Surveyor.

For new ships being constructed, or for existing ships undergoing major repairs, alterations or modifications outside Yugoslavia, the Society's Surveyors are to undertake the relevant surveys only at the specific request of the Jugoslav Register who, in all cases, will issue the respective Certificates.

All reports of surveys and tests made in accordance with the foregoing are to be forwarded direct to the Jugoslav Register through the Society's Split Office without delay and copies of all documents forwarded to London Office for record purposes.

The Surveyor is to state in the report that in his opinion the survey has been satisfactorily completed and the wording "on behalf of the Jugoslavenski Registar Brodova" is to be placed above the Surveyor's signature.

## APPLICATION OF THE CONVENTION REGULATIONS

The Regulations regarding Safety Equipment (not the Collision Regulations which apply to all ships) apply to cargo ships including tankers, of 500 tons gross and over, engaged on international voyages and provided with mechanical means of propulsion. They do not apply to warships, troopships, wooden ships of primitive build such as dhows, junks, etc., pleasure yachts, fishing vessels, nor to ships solely navigating the Great Lakes of North America and the River St. Lawrence as far east as a straight line drawn from Cap des Rosiers to West Point, Anticosti Island and, on the north side of Anticosti Island, the 63rd Meridian.

The Regulations apply in full to new ships, i.e. ships of which keels were/are laid on or after the date of coming into force of the Convention for the particular countries in which the ships are registered. For all practical purposes the 1960 Convention Regulations apply in full to all new ships laid down on or after the 26th May, 1965 (Israeli ships on or after the 1st January, 1962) whether they are registered in a 1960 Convention country or not. This has been the practice of Shipowners since the Convention came into force in order to obtain appropriate documents to allow the ships to trade internationally.

Existing ships, i.e. ships of which the keels were laid before the 26th May, 1965, are now divided into two categories, viz.: —

(1) Ships laid down on or after the 19th November, 1952, and thus complying with the 1948 Convention Regulations which continue to apply to existing equipment and arrangements. Certain requirements of the present Convention which are not contained in the 1948 Convention apply in these cases and details are given in subsequent sections dealing with requirements.

(2) Ships laid down before the 19th November, 1952, before the 1948 Convention came into force and complied with the National Regulations of the country of registration applicable at the time of build. The arrangements in each case are specially considered with a view to improvements being made to provide increased safety where practicable and reasonable. Certain requirements of the present Convention also apply to these ships and are given in subsequent sections dealing with requirements.

All items of equipment on existing ships which are renewed or replaced are to comply with the 1960 Convention requirements and similarly where major alterations or repairs are carried out, the arrangements are to comply with the new Regulations.

**Definitions and abbreviations**

(a) A passenger is every person other than: —
  (i) The Master and the members of the crew or other persons employed or engaged in any capacity on board a ship on the business of that ship; and
  (ii) a child under one year of age.

(b) A passenger ship is a ship which carries more than 12 passengers.

(c) A cargo ship is any ship which is not a passenger ship.

(d) A tanker is a cargo ship constructed or adapted for the carriage in bulk of liquid cargoes of an inflammable nature.

(e) A fishing vessel is a vessel used for catching fish, whales, seals, walrus or other living resources of the sea.

(f) A mile is 6,080 ft or 1,852 m.

(g) Tons = Gross tonnage.

(h) SOLAS = Safety of Life at Sea.

(i) IMCO = Inter - Governmental Maritime Consultative Organisation.

(j) Cert. SEST = Short-term Safety Equipment Certificate.

**Survey procedure on existing ships**

When a request is received from the Owners or their representatives to renew an expired Safety Equipment Certificate, the first consideration is to ensure that the Society is authorised to do so. It is next necessary to ascertain particulars of the previous certificate on board, whether full- or short-term and by whom issued, in order to determine the extent of the survey required. This could be any one of the following: —

(a) Renewal of a full-term certificate issued by the Society or a Cert. SEST issued by the Surveyors in the form of an extension. A complete renewal survey is necessary, together with the preparation of a complete revised Rpt. SE1 if a copy is not already on board.

(b) Renewal of a full-term certificate issued by an Authority other than the Society. A complete renewal survey is necessary, together with the preparation of a complete revised Rpt. SE1.

(c) Renewal of a Cert. SEST issued by one of the Society's Surveyors, other than that issued in the form of an extension. This indicates that a survey has been commenced or advanced previously. The outstanding items shown on the back of the Cert. SEST should be dealt with before issuing a further certificate. If facilities are not available for dealing with the outstanding items, permission to issue a further Cert. SEST should be sought from London Office stating the Owner's proposals for completion of the survey.

(d) Where a Rpt. 10 only has been issued previously, a Cert. SEST may not be issued until all the items mentioned thereon have been satisfactorily dealt with.

**Change of flag**

When a ship changes flag and the Society has not previously issued the Safety Equipment Certificate and is requested to do so on behalf of the Government of the country of new registration, procedure (b) described above is necessary, irrespective of whether the previous certificate continues valid or not.

In certain cases the Owners arrange for the previous valid document to be endorsed by the Consul for acceptance by the Government of the country of new registration and, whilst this procedure is incorrect, the Society cannot intervene as the Consul accepts full responsibility for his actions without realising the implications which might arise at a later date. Surveyors can, however, advise the Consul on these matters and point out the desirability of holding a complete survey in order to ensure that the requirements of his Government are complied with. As already mentioned, Liberian Consuls are not authorised to endorse or accept documents issued by other Governments.

**Extension of certificate**

A Safety Equipment Certificate is issued for a period not exceeding two years, without any intermediate survey being necessary, when it must ordinarily be renewed: it may, however, be extended for a period of grace of up to one month from the date of expiry stated on it.

If a ship at the time when its certificate expires is not in a port of the country in which it is registered or is unable to undergo survey either due to the lack of facilities or other justifiable reason, the certificate may be extended for longer periods with a maximum of five months. Such an extension shall be granted only when it appears reasonable and proper so to do, for the purpose of allowing the ship to complete its voyage to the country in which it is registered or is to be surveyed, where a Safety Equipment Certificate Renewal Survey must be carried out upon arrival.

Surveyors are authorised to extend full-term certificates which have been issued by the Society, for periods up to one month, without reference to London Office, provided they are satisfied that the condition and sufficiency of the equipment warrants such an extension.

Any application for an extension of a certificate for a period longer than one month is to be referred to London Office or, in the case of ships registered in Liberia, to New York Office if more expeditious.

If permission is granted and the equipment and appliances generally examined and found serviceable, the certificate, except in the case of Liberian ships, is to be endorsed "This certificate is extended in accordance with the provisions of the Regulations for a period of grace and will continue to remain in force until . . . day . . . month . . . year". For Liberian ships, the certificate is to be withdrawn and a Cert. SEST issued to the ship bearing the statement "This certificate is issued in the form of an extension to the previous document expiring on the . . . day . . . month . . . year, in accordance with the provisions of the Regulations". Five copies of the Cert. SEST are to be sent direct to New York Office for transmission to the Liberian Authorities.

**Survey procedure on new ships**

When a request is received from the Builders, on behalf of the Owners, for the Society to issue a Safety Equipment Certificate to a new ship, this may be proceeded with provided the Society is authorised to do so. Otherwise, it will be necessary for the Owners to secure written authorisation from the Government of the country in which the ship is to be registered before this task can be undertaken.

Plans showing the life-saving and fire-fighting arrangements are to be forwarded to London Office at an early date for consideration. It is also necessary for the lifeboats and davits to be built under survey to approved plans. If plans of the lifeboats have not previously been approved in London Office, detailed drawings of lines, general arrangement, constructional arrangement, lifting hooks and attachments, motor seating and buoyancy calculations, are to be forwarded for approval. Detail plans of the davits showing their construction and stress calculations are also required.

Items of equipment which are manufactured in a 1960 Convention country and approved by the National Authorities under the provisions of the Convention are generally accepted by the National Authorities of another Convention country in which the ship is to be registered, but it should be noted that only certain types of liferafts are approved by the Liberian Authorities.

The Rpt. SE1 for a new ship should be forwarded to London Office in good time in order to ensure that any queries or discrepancies can be satisfactorily resolved before the ship is delivered. The full-term Safety Equipment Certificate is not normally issued before delivery of a new ship and a short-term certificate is issued by the Surveyor as an interim measure when the survey has been satisfactorily completed.

**Short-term certificates**

When a survey for the issue or renewal of a Safety Equipment Certificate has been satisfactorily completed in its entirety, the Surveyor is to issue a short-term certificate valid for a period of six months pending the issue of a new full-term certificate.

In the case of Liberian ships, the certificate form Cert. SEST (Lib) is to be used (*see* Annex III) and five copies sent direct to the New York Office for transmission to the Liberian Authorities. For all other ships registered in countries which have accepted the 1960 S.O.L.A.S. Convention, the certificate form Cert. SEST is to be used (*see* Annex IV). Copies of any Cert. SEST issued to a Greek or Lebanese ship are to be sent to London in duplicate and a copy of any Cert. SEST issued to an Israeli ship forwarded direct to I.M.O.T. Haifa.

Certificates on the Society's form Cert. SEST are only applicable to ships registered in countries which have acceded to the 1960 Convention. This presents a problem to Owners of ships registered in non-Convention countries and the Society has, therefore, devised a non-Convention Certificate of Survey to meet the needs of Owners whose ships have been surveyed to the standards set by the Convention. Acceptance, or otherwise, of this document in Convention signatory countries is a matter for the Governments concerned. The restricted number of such cases does not justify the printing of special short-term certificate forms and Surveyors should issue a certificate on a Rpt. 10, an example of which is given in Annex V.

Where a survey is incomplete and items of a minor nature are outstanding due to their non-availability and which do not affect the efficiency of the life-saving and fire appliances, a short-term certificate having a restricted validity may be issued for a period not exceeding five months. The validity should be kept to the minimum, bearing in mind the ship's future calling ports and those where replacements, repairs and survey facilities are available. Such a certificate should be headed "CONDITIONAL ISSUE" with full particulars of the outstanding items indicated on the back for the information of all concerned. In addition, the words "except as stated overleaf" should be appended where appropriate to paragraphs III, IV, V and VI of the printed text of the certificate. (*See* Annex VI for example.)

In cases where the efficiency of the life-saving or fire appliances is seriously impaired due to major deficiences or defects, i.e. lifeboats or davits unserviceable, emergency fire pump inoperable, inability to provide the required jets of water for fire-fighting purposes due to defective fire main, hoses or nozzles, etc., the facts should be reported by cablegram to London Office requesting instructions.

(NEW SHIP)

Rpt. SE1

**LLOYD'S REGISTER OF SHIPPING**

# RECORD OF SAFETY EQUIPMENT

**Under the provisions of the International Convention for the Safety of Life at Sea, 1960**

*This form must be kept on board and be available for inspection by Surveyors to Lloyd's Register at all times*

| | Name of Ship | Signal Letters | Nationality and Port of Registry | Gross Tonnage | Date Keel Laid |
|---|---|---|---|---|---|
| 002 | "SPECIMEN I" | 5 LKW | LIBERIAN MONROVIA | 22,998 | 1968 |

| | Previous Name and Nationality | Names of any known Sister Ships |
|---|---|---|
| 003 | | |

004/5 Classification +100A1 Strengthened for Ore Cargoes — LR No. 6926610

006 Name and Address of Owners, Managers or Managing Agents:

A. Shipping Co., Ltd.
61 St. Mary Axe.,
LONDON E.C.3.

| Number of Persons carried | | Length of Ship | |
|---|---|---|---|
| Crew | 40 | B.P. | 620.0' |
| Passengers | - | Regd. | 628.7' |
| Total | 40 | O.A. | 662.0' |

007 The total number of persons provided for by life saving appliances is 41 and no more, viz:—

| | | | |
|---|---|---|---|
| 1 | lifeboats on port side capable of accommodating | 46 | persons |
| 1 | lifeboats on starboard side capable of accommodating | 48 | persons |
| 1 | motor lifeboats (included in the total lifeboats shown above) | | |
| -- | mechanically propelled lifeboats (included in the total lifeboats shown above) | | |
| -- | liferafts {for which approved launching devices are required} capable of accommodating | -- | persons |
| 3 | liferafts {for which approved launching devices are NOT required} capable of accommodating | 30 | persons |
| 8 | lifebuoys | | |
| 41 | lifejackets | | |

008 STABILITY DATA

Is the Master provided with such reliable information as is necessary to enable him by rapid and simple processes to obtain accurate guidance as to the stability of the ship under varying conditions of service? Yes

Has the stability been approved according to the requirements of the 1966 Load Line Convention? Yes

Approved by whom? L.R.

Particulars of Stability Data provided Capacity plan, Hydrostatic curves, Cross curves and statement in various loading conditions.

| | ROCKETS AND SIGNALS | Make | Location |
|---|---|---|---|
| 009 | Line throwing appliance with 4 rockets and lines | Pains-Wessex Lifeline | Chartroom |
| 010 | 12 parachute distress signals | Pains-Wessex Lifechute Mk 6 | " |

Name of Ship LR No.

**FIRE APPLIANCES IN SPACES CONTAINING MAIN AND AUXILIARY MACHINERY AND BOILERS**

011 Type of Propelling Machinery: Internal Combustion

012 Main Boilers—number & type: None — Total number of burners: –

012 Aux. Boilers—number & type: 1 Oil fired vertical — Total number of burners: 1

013 Total BHP of internal combustion machinery used for (a) main propulsion: 14,150 (b) auxiliary purposes: 1,500

014 Are the engine and boiler rooms separate or combined? Combined

| | | Location | Number | Capacity | Type of Prime Mover |
|---|---|---|---|---|---|
| 015 | Fire Pumps (excluding emergency fire pump) | Engine room (p.s.)<br>" " (s.s.) | 1<br>1 | 120 t/h<br>90 t/h | Electric motor<br>" " |
| 016 | Emergency Fire Pump | Fore peak compt. | 1 | 48 t/h | Diesel engine |
| 017 | Hydrants | Eng. Rm floor (lp&ls)<br>E.R. casing (p.s.) | 2<br>1 | Diameter<br>2½"<br>2½" | Type of Coupling<br>Instantaneous<br>" |
| 017 | Hoses, with nozzle for each | One at each hydrant | 3 | 2½" | Length: 50ft. Material: canvas Nozzle: comb. |

018 In each firing space is there either (a) a box containing 10 cu. ft. sand with scoop? Yes at auxy boiler

or (b) a 2 gal. fire extinguisher discharging foam? --

| | | Location | Number | Capacity | Type | Make |
|---|---|---|---|---|---|---|
| 019 | Portable Extinguishers | E.R. distributed<br>" "<br>E.R. switchboard | 2<br>12<br>2 | 10 lbs.<br>2 gall<br>7 lbs. | D.P.<br>Foam<br>CO2 | Angus<br>"<br>" |
| 020 | Is one spare charge provided for each? | Yes | | | | |
| 021 | Non-portable Extinguishers | Boiler flat | 1 | 10 gall | Foam | Angus |

022 Fixed fire-smothering system. State type installed.
Where carbon dioxide is used give number, capacity and location of cylinders

023 CO2 Total flooding system. 99 cylinders each 99 lbs. capacity located in compartment on poop deck (p.s.f.)

Location of Control Valves: Poop deck starboard alleyway

Audible warning of the release of smothering gas: Klaxon horn.

030

| Means for stopping machinery and shutting off O.F. Suction Pipes | Means and Location | Can the following be closed from outside the space concerned? | |
|---|---|---|---|
| Vent. fans | Stop switches - E.R. alleyway (s.s) | Ventilators | Yes |
| I.D. fans | -- | Funnel annular spaces | Yes |
| F.D. fans | Stop switch - E.R. alleyway (s.s.) | Skylights | Yes |
| O.F. trans. pump | Stop switches - " " " | Doorways | Yes |
| O.F. units | Stop switches - " " " | Tunnel door | Yes |
| O.F. tank valves | Q.C. gear - Casing top | | |

Name of Ship "SPECIMEN I" LR No. 6926610

**FIRE APPLIANCES OUTSIDE MAIN AND AUXILIARY MACHINERY AND BOILER SPACES**

024/5 Fixed fire smothering system in cargo spaces or on oil tank decks of ships 2000 tons gross and over. State type installed. Where carbon dioxide is used give number, capacity and location of cylinders

Not fitted

024(4) If no smothering system is fitted other than in the tanks of a tanker one of the following must apply:—
(a) Are hatch covers of steel, and effective means provided for closing all ventilators and other openings leading to the holds? Yes

(b) Is the ship constructed and intended solely for carrying such cargoes as ore, coal or grain? Yes

HYDRANTS

Is the number and position of hydrants such that at least two jets of water, not emanating from the same hydrant, one of which is from a single length of hose, may reach any part of the ship normally accessible to passengers or crew while the ship is being navigated? Yes

Is the number and position of hydrants such that at least two jets of water can reach any part of any cargo space when empty? Yes

| | | Location | Number | Diameter | Type of Coupling | | |
|---|---|---|---|---|---|---|---|
| 031 | Hydrants | Decks & accommodation distributed | 23 | 2½" | Instantaneous | | |
| | | | | | Length | Material | Nozzle |
| 031 | Hoses, with nozzle for each | Decks & accommodation distributed | 5<br>2 | 2½"<br>2½" | 60ft<br>50ft | canvas<br>Canvas | jet<br>jet |
| 032 | International Shore Connection | Deck office | 2 | Are facilities available enabling the connection to be used on either side of the ship? | | | Yes |
| | | | | Capacity | Type | Make | |
| 033 | Portable Extinguishers | Crew spaces<br>Galley<br>Radio Room<br>Contactor Room<br>Battery Lkr<br>Emergency Gen. Rm. | 9<br>1<br>1<br>1<br>1<br>1 | 2 gall<br>7 lb<br>7 lb<br>7 lb<br>7 lb<br>7 lb | S.Acid<br>CO2<br>CO2<br>CO2<br>CO2<br>CO2 | Angus<br>"<br>"<br>"<br>"<br>" | |
| 033(e) | Is one spare charge provided for each? | Yes | | | | | |

034 Firemen's outfits, each comprising an approved breathing apparatus with lifeline; a safety lamp and an axe with short insulated handle and carrying belt. State number carried and location of each outfit.

One Deck Office
One Engineers Office
One Aft Masthouse

030 Can the ventilator fans be stopped and doorways, ventilators and all other openings to cargo spaces be closed from outside the space concerned? Yes

035 State whether fire control plans ~~or booklets~~ are provided Yes

Ship's Name "SPECIMEN I" LR No. 6926610

## LIFE-SAVING APPLIANCES

### LIFEBOATS

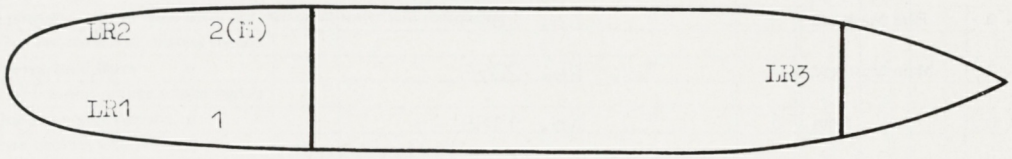
| | No. on Sketch | Description | Dimensions (metres/feet) Length | Breadth | Depth | Cubic Capacity (cu.m./cu.ft.) | No. of Persons | Air Cases Material | Air Cases Volume (cu.m./cu.ft.) |
|---|---|---|---|---|---|---|---|---|---|
| 036 | 1 | G.R.P. Pulling | 24.00 | 8.25 | 3.50 | 488 | 48 | Foam | 79 |
| | 2 | G.R.P. Motor | 24.00 | 8.25 | 3.50 | 466 net | 46 | Foam | 79 |

037(b) Arrangements to facilitate launching against adverse list: Skates on boats Skids at Bulwark openings

037(c) Method of releasing lifeboat from falls: Long links

037(d) Means of lowering lifeboats: Winch and brake

Indicate superstructures and positions of lifeboats and liferafts. Indicate M or MP boats.
Lifeboats numbered from forward, odd numbers starboard, even numbers port.




### DAVITS

| | Boat No. | Description | SWL | Boat Falls Size, Construction and Material | Breaking Strain |
|---|---|---|---|---|---|
| 038 | 1&2 | Welin Gravity Pivot type | 3.0 tons | 2" circ. 18 x 7 EIWRC | 14.5 tons |

038(d) Are the davits of sufficient strength to lower fully-laden boats? Yes

### LIFERAFTS

| | No. | Description | Maker's Name and Serial Nos. | No. of Persons | Location |
|---|---|---|---|---|---|
| 036 | 1 | Inflatable | R.F.D. Serial No.1308 | 12 | Boat deck (s) |
| 039 | 2 | Inflatable | " " " 1308 | 12 | Boat deck (p) |
| | 3 | Rigid | Walter Tangen No. 8736 | 6 | Fcle front |

| OTHER LIFE-SAVING APPLIANCES | No. | Description | Location |
|---|---|---|---|
| 042 Lifejackets with whistle attached | 41 | B.C.T. approved | One in each cabin |
| 043 Lifebuoys with lights and smoke signals and capable of quick release | 2 | Circular cork | Bridge wings p & s |
| 043 Lifebuoys with self igniting lights only | 2 | Circular cork | Poop deck p & s |
| 043 Lifebuoys with 15 fms (27·5 m) buoyant lifeline | 2 | Circular cork | Boat deck p & s |
| 043 Lifebuoys without attachments | 2 | Circular cork | Captain's bridge p&s |

### PILOT LADDERS

044 Is a ladder provided for the safe embarkation and disembarkation of pilots with provision for adequate overside lighting at night? Yes

Name of Ship "SPECIMEN I" LR No. 6926610

**EMBARKATION ARRANGEMENTS**

040(b) Is an embarkation ladder provided for each lifeboat and liferaft? Yes

040(d) Are bowsing tackles provided to hold the boats against the ship's side? Yes

040(e) Means of preventing any discharge of water into lifeboats No discharges in way

040(f) Are muster lists posted in several parts of the ship? Yes

040(g) Type of warning system for abandoning ship Alarm bells operated from bridge

040(h) Are the stowage and launching positions provided with adequate lighting? Yes

041 Source and position of power for emergency lighting Independent generator fwd end poop space

**LIGHTS AND SOUND SIGNALS**

045 NAVIGATION LIGHTS

| | Position of Light | No. | OIL Marks and Nos. | No. | ELECTRIC Marks and Nos. |
|---|---|---|---|---|---|
| 045(a) | Port side | 1 | "Murray" No. 1210 | 1 | "Murray" No. 739 |
| 045(a) | Starboard side | 1 | " No. 1205 | 1 | " No. 726 |
| 045(a) | Fore Masthead | 1 | " No. 2075 | 1 | " No. 1273 |
| 045(a) | Main Masthead† | 1 | " No. 2076 | 1 | " No. 1274 |
| 045(b) | Stern | 1 | " No. 1188 | 1 | " No. 1121 |
| 045(c) | Anchor (1) | 1 | " No. 1058 | 1 | " No. 1462 |
| 045(c) | Anchor (2)† | 1 | " No. 1059 | 1 | " No. 1465 |
| 045(d) | NUC (1) | 1 | " No. 1561 | | |
| 045(d) | NUC (2) | 1 | " No. 1562 | | |

†not required on ships less than 150 feet overall length

045(e) Breadth of screening chocks amidships — Port: Oil 6", Elec. 6" — Stbd.: Oil 6", Elec. 6" — Number of spare lamps 045(f)

045(g) Where oil navigation lights are not provided, are the electric lamps of duplex type with double independent wiring and source of power? --

State source of independent power --

| 046 | SIGNALLING APPARATUS | No. | Description | Location |
|---|---|---|---|---|
| 046(a) | Daylight signalling lamp and source of power | 1 | Aldis long range 12V., Serial 5889 | Chartroom |
| 046(b) | Forecastle Bell | 1 | 12" dia. | Fcle deck |
| " | Foghorn | 1 | Rotary type | Chartroom |
| " | Gong (*ships over 350 ft. O.A.*) | 1 | 16" dia. with striker | Deck office |
| " | Ship's Whistle | 2 | Air typhon | 1 - Funnel<br>1 - Foremast |
| 046(c) | 3 black ball shapes 2ft. dia. | 3 | Steel folding shapes | Lamp room |
| " | 1 black diamond shape 2 ft. dia. | 1 | Steel folding shape | |

Any other lights or shapes carried None

Name of Ship "SPECIMEN I" LR No. 6926610

047 **LIFEBOAT EQUIPMENT**

| | *Each lifeboat is equipped as follows:* | BOAT NUMBER 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| | Number of persons the boat is certified to carry | 48 | 46 | | |
| | Indicate boats motor (M) or mech. propelled (MP) | | M | | |
| (1) | Two crutches or equivalent for each rowing thwart (plus 50% spares) with chain or lanyard | 10 | 10 | | |
| (2) | Two plugs for each plug hole with chain attachment or automatic valves in lieu | 2 | 2 | | |
| (3) | An attached rudder with tiller | 1 | 1 | | |
| (4) | Lifeline becketed around outside of boat | Yes | Yes | | |
| (5) | Bilge keels or keel rails | Yes | Yes | | |
| (5) | At least two grablines gunwale to gunwale under keel | 3 | 3 | | |
| (6) | One manually operated bilge pump | 1 | 1 | | |
| (7) | Suitable locker for stowage of small items of equipment | 1 | 1 | | |
| (8) | Two painters, one secured to stem, the other secured forward with strop and toggle | 2 | 2 | | |
| (9) | Two light buoyant heaving lines | 2 | 2 | | |
| (10) | One rowing oar to each rowing thwart (Half for M and MP boats, four minimum) | 4 | 4 | | |
| (11) | Two spare rowing oars (Not required for M and MP boats) | 2 | – | | |
| (12) | One steering oar with white painted blade | 1 | 1 | | |
| (13) | One boat hook (2 for M or MP boats) | 1 | 2 | | |
| (14) | Mast with galvd. wire stays and orange sails (Not required for M or MP boats) | 1 | Nil | | |
| (15) | One highly visible cover for protecting occupants | 1 | 1 | | |
| (16) | 2lbs (or 1kg) approved provisions per person } in airtight receptacles and stowed | 2lbs | 2lbs | | |
| (17) | 1lb (or ½kg) condensed milk per person } in watertight containers | 1lb | 1lb | | |
| (18) | 6 pints (or 3 litres) fresh water per person in watertight receptacles | 6pts | 6pts | | |
| (19) | Four red parachute distress signals | 4 | 4 | | |
| (19) | Six red hand flares | 6 | 6 | | |
| (19) | Two buoyant orange smoke signals | 2 | 2 | | |
| (20) | One baler with lanyard | 1 | 1 | | |
| (21) | Two buckets with lanyards | 2 | 2 | | |
| (22) | Two hatchets with lanyards | 2 | 2 | | |
| (23) | One lamp with 12 hours supply of oil | 1 | 1 | | |
| (24) | Two boxes of matches in watertight container | 2 | 2 | | |
| (25) | A luminised or illuminated compass in binnacle | 1 | 1 | | |
| (26) | One sea anchor | 1 | 1 | | |
| (27) | 1 gall. (4½ litres) storm oil | 1g | 1g | | |
| (28) | One storm oil bag for attaching to sea anchor | 1 | 1 | | |
| (29) | One rustproof dipper with lanyard | 1 | 1 | | |
| (30) | One rustproof graduated drinking vessel | 1 | 1 | | |
| (31) | First aid outfit in watertight case | 1 | 1 | | |
| (32) | A waterproof electric torch suitable for Morse Code signalling with one spare set of batteries and one spare bulb in a waterproof container | 1 | 1 | | |
| (33) | One daylight signalling mirror | 1 | 1 | | |
| (34) | One jack-knife with tin opener and lanyard | 1 | 1 | | |
| (35) | One whistle or reed horn | 1 | 1 | | |
| (36) | One set fishing tackle | 1 | 1 | | |
| (37) | One copy of the illustrated table of life-saving signals | 1 | 1 | | |
| (38) | One short ladder or other means for climbing into upright boat from water | 1 | 1 | | |
| | **Motor lifeboats** Type of engine, petrol driven (P) or diesel driven (D) | | D | | |
| | Fuel capacity sufficient for 24 hours running Galls | | 24 | | |
| (39) | Two hand fire extinguishers | | 2 | | |

(40) Is each lifeboat permanently marked with dimensions and the number of persons which it is permitted to carry? Yes

Is the name and port of registry of the ship to which each lifeboat belongs painted on each side of the bow? Yes

048 LIFEBOAT PORTABLE RADIO APPARATUS

Type, Manufacturer and Serial No. Marinetta Type Disa 71A16 Serial No. 1029

State location on board Chartroom

Name of Ship "SPECIMEN I" LR No. 6926610 **Rpt. SE1 (Sheet 7)**

049 **RIGID LIFERAFT EQUIPMENT**

| | *Each rigid liferaft is equipped as follows:* | RAFT NUMBER 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| | Number of persons the liferaft is certified to carry | | | 6 | |
| (1) | One attached painter | | | 1 | |
| (2) | Lifeline becketed around outside of liferaft | | | 1 | |
| (3) | Lifeline fitted around inside of liferaft | | | 1 | |
| (4) | Two sea anchors (one permanently attached and one spare) | | | 2 | |
| (5) | One buoyant battery type light attached by lanyard | | | 1 | |
| (6) | 12 ozs. approved provisions per person | | | 12oz | |
| (7) | 6 ozs. barley sugar or equivalent per person | | | 6oz | |
| (8) | 3 pints (or 1½ litres) fresh water per person in watertight receptacles | | | 3p | |
| (9) | Six anti-seasickness tablets per person | | | 6 | |
| (10) | Two paddles | | | 2 | |
| (11) | One first aid outfit in waterproof case | | | 1 | |
| (12) | Two red parachute signals | | | 2 | |
| (13) | Six red hand flares | | | 6 | |
| (14) | One buoyant rescue quoit attached to 100 feet (or 30 metres) of buoyant line | | | 1 | |
| (15) | One knife and one baler (for liferafts carrying less than 13 persons) | | | 1+1 | |
| (16) | Two knives and two balers (for liferafts carrying more than 12 persons) | | | – | |
| (17) | Two sponges | | | 2 | |
| (18) | One outfit for repairing punctures in buoyancy compartments | | | 1 | |
| (19) | Three tin openers | | | 3 | |
| (20) | One rustproof graduated drinking vessel | | | 1 | |
| (21) | One waterproof electric torch suitable for Morse Code signalling with one spare set of batteries and one spare bulb in a waterproof container | | | 1 | |
| (22) | One daylight signalling mirror | | | 1 | |
| (23) | One signalling whistle | | | 1 | |
| (24) | One set fishing tackle | | | 1 | |
| (25) | Survival instructions | | | 1 | |
| (26) | One copy of the illustrated table of life-saving signals | | | 1 | |
| | Is each rigid liferaft marked with the name and port of registry of the ship in which it is carried and with the number of persons it is permitted to carry? | | | Yes | |
| | INFLATABLE LIFERAFTS | | | | |
| | Is each inflatable liferaft certified to contain Full Emergency Pack equipment for the number of persons it is permitted to carry in accordance with the provisions of the Regulations for long international voyages? | Yes | Yes | | |
| | Is the valise or container of each inflatable liferaft marked with the number of persons the raft is certified to carry? | Yes | Yes | | |

Particulars of any special features or additional information

None

The information contained in this report is a correct description of the Safety Equipment on board at the time of inspection. The equipment is in an efficient condition.

Date of Inspection During construction 9.70 A.N.Other

Port LONDON

*Surveyor(s) to Lloyd's Register of Shipping*

# PART II

## REQUIREMENTS ON NEW AND EXISTING SHIPS

### Record of safety equipment

The revised Rpt. SE1 is to be brought into use as soon as supplies are received from the Printing House. It is to be completed for all new ships and for all existing ships undergoing initial and renewal surveys in future until a new form is prepared for each ship dealt with by the Society.

Careful preparation of the Rpt. SE1 will obviate the necessity for the Surveyor to be faced with the difficult task of answering queries raised by London Office some time after the survey was held. Furthermore, it is the Surveyor's duty to ensure that any deficiencies are made good and the equipment is in accordance with Regulations during the survey and not merely to report what is on board.

It must be borne in mind that a copy of the Rpt. SE1 will eventually be placed on board the ship for the guidance of the Surveyors at subsequent surveys and remarks as to the condition of the equipment or comments such as "To be supplied", "Not examined", etc., should not be made on this form.

Every effort must be made to complete the Rpt. SE1 of an existing ship in its entirety in one operation in order that the case may be examined in London Office and a Safety Equipment Certificate issued as soon as possible. Receipt of a partial Rpt. SE1 only leads to unnecessary correspondence between London Office, the Owners and the Surveyors and causes much delay and inconvenience.

A typical example of the completed Rpt. SE1 is reproduced for the Surveyors' guidance and the requirements of the Regulations are detailed as follows according to the reference numbers shown.

**001.** A copy of the form is not provided on board by the Surveyor carrying out the initial survey. In the first instance, the completed form is to be sent to London Office where the details are checked and, if all is in order, a xerox copy is issued to the Owners for retention on board the ship.

**002.** If any particulars are not known the space should be left blank. In some cases, change of registration also means change of gross tonnage, in which case, the tonnage figure should not be entered, unless the new tonnage is known. The keel-laying date is required to define whether the ship is a "new ship" or an "existing ship". This may be approximated except for 1952 and 1965 in which cases the actual day and month is required so that it may be determined which Convention is applicable.

**003.** The previous name and nationality, where applicable, should be stated, as this is helpful when the case is being examined in London Office, as is the name of any sister ships.

**004.** Classification particulars from the Register Book in respect of the Hull only are required. These should include details of any restricted service limits imposed.

**005.** Certain National Authorities allow several ships to have the same name therefore the L.R. number is of assistance in identifying the case under consideration.

**006.** Particulars are required of the Company which actually manages the ship, pays the fees and receives all correspondence and documents. This information is of utmost importance and of great assistance to the International Conventions Department in ensuring that certificates and correspondence are forwarded to the correct address.

**007.** The total number of persons provided for by life-saving appliances is not to be confused with the actual number of persons carried. This number is equal to the lowest of the following:—

(a) The total number of persons in the port lifeboat(s).

(b) The total number of persons in the starboard lifeboat(s).

(c) Twice the aggregate capacities of liferafts, where applicable, but excluding any liferaft carried forward.

(d) The total number of lifejackets.

### 008. Stability data

This subject is dealt with in detail in the Staff Association paper "1966 LOAD LINE CONVENTION: ITS IMPLICATIONS AND INTERPRETATIONS" presented at the last session, as the provision of stability data is a condition attached to the assignment of freeboards under the 1966 Load Line Convention. Reg. 19, Ch. II of 1960 S.O.L.A.S. Convention requires that the master of every new ship shall be supplied with such reliable information as is necessary to enable him by rapid and simple processes to obtain accurate guidance as to the stability of ship under varying conditions of service, whereas the previous Convention was not so explicit and required the supply of such information on this subject as is necessary to permit efficient handling of the ship.

It naturally follows, therefore, that all new ships are to be provided with a manual of stability information for all conditions of ballasting and loading, together with Capacity Plan, Hydrostatic Curves and Cross Curves of Stability. This also applies to all existing ships with freeboards assigned under the 1966 Load Line Convention.

*All* existing ships registered in Greece, irrespective of age, are to be supplied with relevant stability data. Whenever it is found upon renewal of a Safety Construction or Load Line Certificate, that the data is not available, the Owners are required to comply with the requirements at the earliest opportunity, a reasonable time being allowed for the preparation of the necessary information. The delay, however, is not to exceed 12 months for ships which already have hydrostatic curves and six months after the next drydocking for vessels which have not been subjected to an inclining experiment. The stability data is to be witnessed and approved by the Classification Society issuing the relevant certificate.

Other existing ships, the keels of which were laid down after the 19th November, 1952, should also have some form of stability information on board, but in cases of ships laid down before that date the provision of data depends upon the National Regulations of the country of registration at the time of build.

Full details of the stability data available should be reported and, if it is not known whether the 1966 Load Line Convention applies, the space should be left blank and a covering note attached to the report.

Each individual case will be examined by the International Conventions Department at Headquarters, both from the Load Line and S.O.L.A.S. Conventions points of view and, where applicable, the Owners will be informed of the requirements for compliance with the relevant Regulations.

**009. Line-throwing appliance**

Every new and existing ship is required to carry a line-throwing appliance containing at least four lines and four projectiles, capable of throwing a line over a minimum distance of 250 yards (or 230 metres) with reasonable accuracy in calm weather. The rockets and cartridges are to be stamped indelibly with the date of manufacture and renewed when three years old. An appliance approved by a National Authority subscribing to the Convention is acceptable.

Approved line-throwing appliances of British manufacture which are available in many parts of the world are: —

(1) "Schermuly International Set", in a wooden carrying case comprises, a 41 mm. rocket pistol with cleaning materials and brush, four 41 mm. line rockets, four 300 yards buoyant polyolefin lines and five ignition cartridges.

(2) "Schermuly Supreme Set", discontinued in 1956 and superseded by the "International" to which it is similar except for 350 yards flax line and a 51 mm. rocket employed to throw the heavier line. Replacements continue to be available.

(3) "Pains-Wessex Lifeline" is a self-contained unit incorporating its own firing mechanism, rocket and prepacked line, therefore, four such units are required.

**010. Ships' distress signals**

Every new and existing ship is required to carry at least 12 parachute distress rocket signals, each capable of producing a single bright red star at a high altitude, its rate of fall being controlled by means of a parachute. Rockets approved by a National Authority subscribing to the Convention may be either the hand held or stick type and, if the latter is provided, a firing bracket is to be fitted on each side of the ship.

The rockets are to be packed in watertight containers, stowed in a dry place and stamped with the date of filling. As for other pyrotechnics, renewal is required when three years old.

**Fire appliances in spaces containing main and auxiliary machinery and boilers**

**011. Type of propelling machinery**

In order to apply the relevant requirements of the Regulations, a brief description of the propelling machinery is required. "Internal Combustion", "Steam Reciprocating" or "Steam Turbines" will provide the necessary information.

**012. Main and auxiliary boilers**

Similarly, information is required regarding the number and type of boilers installed, whether coal- or oil-fired, and the total number of burners.

**013. Internal combustion machinery**

The B.H.P. of internal combustion machinery used for (a) main propulsion and (b) auxiliary purposes is to be entered in the appropriate space.

**014. Engine and boiler rooms**

The compartments are to be considered from the point of view of fire spread and are separate when they are efficiently bulkheaded from each other so that there is little likelihood of a fire in one compartment spreading to another. If the engine and boiler rooms are not entirely separate, or if fuel oil can drain from the boiler room into the engine room bilges, the engine and boiler rooms are to be considered as one compartment and therefore combined.

**015. Fire pumps, excluding emergency fire pump**

(1) All ships are to be provided with appliances whereby at least two jets of water having a throw of 40 ft. (12,2 m.) can reach any part of the ship normally accessible to the passengers or crew while the ship is being navigated, and any storeroom and any part of any cargo space when empty.

(2) All ships of less than 1,000 tons, not less than two power pumps are to be provided, one of which is to be an independent pump, each of which shall be capable of delivering at least one jet of water from a hose and nozzle coupled to any hydrant in the ship.

(3) All ships of 1,000 tons or over shall be provided with two independently driven power pumps. Each such pump shall be capable of delivering at least one jet simultaneously from each of any two hydrants in the ship.

(4) Independently driven sanitary, ballast, bilge or general service pumps may be accepted as fire pumps, provided that they are not normally used for pumping oil and that if they are subject to occasional duty for the transfer or pumping of fuel oil, suitable change-over arrangements are fitted.

(5) The total quantity of water to be available for fire fighting purposes is to be not less than two-thirds of the required bilge pumping capacity of the ship, with a minimum of 20 and a maximum of 180 tons/hr. as given in the following table where

L = length of ship between perpendiculars.

B = greatest moulded breadth.

D = depth to bulkhead deck amidships.

A = total fire pump capacity, $m.^3$/hr. or tons/hr.

| L(B+D) $ft.^2$ | L(B+D) $m.^2$ | A |
|---|---|---|
| 2500 | 232 | 20 |
| 3906 | 363 | 25 |
| 5625 | 623 | 30 |
| 7656 | 711 | 37 |
| 10000 | 929 | 45 |
| 12656 | 1176 | 53 |
| 15625 | 1451 | 61 |
| 18906 | 1756 | 70 |
| 22500 | 2090 | 80 |
| 26406 | 2453 | 90 |
| 30625 | 2845 | 100 |
| 35156 | 3266 | 112 |
| 40000 | 3716 | 124 |
| 45156 | 4195 | 137 |
| 50625 | 4703 | 150 |
| 56406 | 5240 | 165 |
| 62500 | 5806 | 180 |

(6) Where the two fire pumps are of different capacities, the smaller pump capacity is to be not less than 40 per cent of the total fire pump capacity required and in any event is to be capable of delivering at least the required jets of water. Any deficiency in the capacity of one pump is to be made good by excess capacity of the other pump. Where more pumps than required are installed their capacities will be specially considered.

(7) Relief valves are to be provided in conjunction with all fire pumps if the pumps are capable of developing a pressure exceeding the design pressure of the water service pipes, hydrants and hoses. These valves are to be so placed and adjusted as to prevent excessive pressure in any part of the fire main system.

(8) In the case of new ships, the 1960 Convention stipulates that the diameter of the fire main and water service pipes are to be sufficient for the effective distribution of the maximum required discharge from two fire pumps operating simultaneously, but the diameter need not be greater than that required for the discharge of 140 tons per hour.

So far as is known no Administration has yet produced a formula for the ready calculation of the diameter of the fire main, but on the basis of the bilge suction main sizes, calculated on a flow of 400 ft. per minute, the following table can be used as a guide in determining the size of the fire main where C is the total capacity of water available in $m.^3$/hr. or tons/hr.:—

| C | Fire main in. | Dia. mm. |
|---|---|---|
| 30 | 2 | 51 |
| 38 | $2\frac{1}{4}$ | 57 |
| 46 | $2\frac{1}{2}$ | 63·5 |
| 56 | $2\frac{3}{4}$ | 70 |
| 68 | 3 | 76 |
| 80 | $3\frac{1}{4}$ | 82·5 |
| 92 | $3\frac{1}{2}$ | 89 |
| 106 | $3\frac{3}{4}$ | 95 |
| 120 | 4 | 102 |
| 136 | $4\frac{1}{4}$ | 108 |
| 152 | $4\frac{1}{2}$ | 114 |

The fire main is not to be less than 2 in. diameter and, to cater for the stated maximum of 140 tons per hour, need not be greater than $4\frac{1}{2}$ in. diameter.

(9) In existing ships the capacity of the fire pumps may not be available and need not be stated, but the Surveyor is, however, to be satisfied with the effectiveness of the arrangements for providing the required two jets of water for fire-fighting purposes.

**016. Emergency fire pump**

(1) In all new ships of 1,000 tons and upwards, if a fire in any one compartment could put all the fire pumps out of action, either by disabling the pumps or their source of power, there must be an alternative means of providing water for fire fighting. This alternative means is to be a fixed emergency pump independently driven by a compression ignition engine, or other approved means and having a capacity of not less than 15 $m.^3$ (15 tons) per hour in ships of 1,000 tons and over but not exceeding 2,000 tons, and not less than 25 $m.^3$ (25 tons) per hour in ships of 2,000 tons and over. This emergency pump is to be capable of supplying two jets of water having a throw of not less than 40 ft., through hoses and nozzles coupled to any of the fire hydrants in the ship. The pump is to be located remote from the machinery space; e.g. in ships with machinery amidships the pump should be installed in the tunnel or steering gear compartment, and in ships with machinery aft the pump preferably should be located forward. If the unit is in the shaft tunnel, the tunnel watertight door should be fitted with means of closing from a position outside the engine room, so that the tunnel can be made into a separate compartment. The pump is to be provided with its own sea suction and a discharge to the fire main and is to be capable of being fully operational with the ship in light seagoing condition. The fuel service tank for the engine is to have a capacity for at least three hours' operation of the emergency pump and, in addition, sufficient fuel is to be available to enable the pump to run for a period of 12 hours. In the event of an accident in the engine room which may result in damage to the main fire pumps or discharge line to the fire main, it is necessary to fit an isolating valve at the point where the rising main from the engine room joins the fire main in order to ensure that the emergency fire pump will maintain the required pressure.

(2) With regard to existing ships, the 1948 Regulations required ships of 1,000 tons and upwards fitted with oil-fired boilers or internal combustion machinery, to be provided with an "alternative means" of fire extinguishing in the event of a fire in any one compartment rendering all the fire pumps inoperable. The absence of the word "water" which appears in the 1960 Convention led to the acceptance of a smothering gas installation as an alternative means as, with such an extinguishing system, if a fire occurred in the compartment containing the fire pumps or their source of power, the space could be evacuated and the fire dealt with by releasing the smothering gas from outside.

In existing ships, therefore, the alternative means of extinguishing a fire may be met by providing an independently driven fire pump or a fixed smothering gas installation. Systems discharging froth or steam are not acceptable for this purpose. Ships of 1,000 tons and upwards having oil-fired main and auxiliary boilers were also required to be fitted with appliances whereby froth, steam, high pressure water-spray or smothering gas could be rapidly discharged into the boiler room and any space in which oil fuel units or settling tanks were situated and, if a smothering gas system was already installed to comply with this requirement, the question arose, does this also provide the "alternative means" required by the other section of the Regulations—and if not, how many "means" and " alternative means" are necessary?

As the Regulations cater only for the outbreak of fire in any one compartment at any one time several National Authorities considered it reasonable to accept the carbon dioxide system already installed as providing the "alternative means" required, whereas others followed the British Merchant Shipping Rules which called for an extra quantity of $CO_2$ in lieu of an emergency fire pump.

As the existing ships dealt with by the Society were built in accordance with the specific requirements of various National Authorities, no single ruling can be applied and each case will be examined on its merits and will be accepted provided the minimum requirements have been met.

**017. Hydrants, hoses and nozzles**

(1) In all ships of 1,000 tons and over, at least two hydrants, one port and one starboard, are to be provided in each separate compartment containing machinery and boilers. One

hydrant in each space is acceptable in ships of less than 1,000 tons.

(2) Hydrants in such spaces may be $1\frac{1}{2}$ in. diameter, each fitted with a valve or cock and instantaneous, hermaphrodite or screw-type couplings.

(3) Each hydrant is to be provided with a hose of sufficient length to enable an effective spray of water to reach any part of the machinery or boiler spaces.

(4) Each hose is to be provided with a jet nozzle and in oil-burning steamships and in motorships an additional spray nozzle, of a type suitable for fighting oil fires, is also required for each hose. Combined jet-spray nozzles are accepted as satisfying both requirements.

**018. Sand in firing spaces**

All ships of 1,000 tons and over having oil-fired main or auxiliary boilers, are to be provided, in each firing space, with a receptacle containing at least 10 cu.ft. (0,28 m.$^3$) of sand, sawdust impregnated with soda, or other approved dry material suitable for quenching oil fires, together with a scoop for distributing this material. Alternatively, a portable fire extinguisher suitable for extinguishing oil fires may be provided in lieu.

**019. Portable extinguishers**

(1) All ships with oil-fired main or auxiliary boilers are to be provided with:—

(a) In each boiler room firing space and in each space which contains any part of any oil-fuel installation at least two portable fire extinguishers suitable for extinguishing oil fires and, in addition,

(b) At least one portable fire extinguisher for each burner where the number of burners in the boiler room is less than five. Where there are five or more burners one foam extinguisher of at least 10 gallons (45 litres) capacity (*see* 021(2).)

(2) For all ships where internal combustion type machinery is installed either (a) for main propulsion or (b) for auxiliary purposes associated with a total power of not less than 1,000 b.h.p. portable extinguishers are to be provided in accordance with the following scale:—

| B.H.P. of I.C. Machinery | Extinguishers |
|---|---|
| not exceeding 2,000 | 2 |
| over 2,000 but not over 3,000 | 3 |
| over 3,000 but not over 4,000 | 4 |
| over 4,000 but not over 5,000 | 5 |
| over 5,000 | 6 |

(3) In separate spaces containing steam turbines or enclosed pressure lubricated steam engines used either for main propulsion, or having in the aggregate a total power of not less than 1,000 b.h.p. for auxiliary purposes, portable extinguishers are required on the same scale given in paragraph (2) above.

(4) An extinguisher is also to be provided for dealing with fires at switchboards and other electrical appliances. Extinguishers discharging foam are unsuitable and those containing a non-conducting medium such as carbon dioxide, dry chemical or carbon tetrachloride are to be used but as the latter type gives off a toxic vapour in the form of phosgene gas upon contact with heat, its size is to be restricted to 1 quart (1,136 litres).

(5) The cargo pump rooms in tankers are to be provided with two portable foam extinguishers or equivalent, one at the pumps and one at the pump room entrance.

(6) Cargo pump rooms and compressor rooms of liquefied gas carriers are to be provided with two portable dry chemical extinguishers or equivalent in each space.

(7) A "portable extinguisher" is one that is capable of being easily carried and the fluid type is not to exceed 56 lb. (25 kg.) in weight in the fully charged service condition and its capacity is not more than 3 gallons (13,5 litres) nor less than 2 gallons (9 litres).

Other types of extinguishers are to have a capacity of not less than 7 lb. (3 kg.) of carbon dioxide or 10 lb. (4,5 kg.) dry powder.

**020. Spare charges**

A spare charge is to be provided for every portable fire extinguisher, except that for each fire extinguisher which is of a type that cannot be readily recharged while the ship is at sea (such as carbon dioxide), an additional portable fire extinguisher of the same type, or its equivalent, is to be provided in lieu of a spare charge.

**021. Non-portable extinguishers**

(1) Non-portable fire extinguishers are those which exceed 3 gallons (13,5 litres) fluid capacity or equivalent.

(2) All ships with oil-fired main or auxiliary boilers are to be provided in each boiler room firing space, with one foam extinguisher of at least 10 gallons (45 litres) capacity or a carbon dioxide extinguisher of at least 35 lb. (16 kg.) capacity if the number of burners therein is five or more.

(3) For all ships where internal combustion-type engines are used, either (a) for main propulsion machinery, or (b) for auxiliary purposes associated with a total power of not less than 1,000 b.h.p., one foam extinguisher of at least 10 gallons (45 litres) capacity or a carbon dioxide extinguisher of at least 35 lb. (16 kg.) capacity is to be provided in the space containing such machinery.

**022. Fixed fire extinguishing installations in spaces containing oil-fired boilers or oil-burning equipment**

(1) In all ships a fixed fire extinguishing installation is to be provided for the protection of any space containing any oil-fired boiler, oil-fuel settling tank or oil-fuel unit.

(2) If the engine and boiler rooms are not entirely separated from each other by a bulkhead, or if fuel oil can drain from the boiler room into the engine room, the combined engine and boiler rooms are to be regarded as a single space.

(3) The various types of fixed fire extinguishing installations applicable are as follows:—

(a) A pressure water spraying system.

(b) A fire smothering gas installation.

(c) A fixed froth installation.

(d) A fixed fire smothering steam installation.

(4) For new and existing ships at least one of the fixed installations mentioned in paragraph 022(3) is to be provided as indicated below:—

| | 500 tons and over but less than 1,000 tons | 1,000 tons and over |
|---|---|---|
| New ships | a, b, c or d | a, b, or c |
| Existing ships | a, b, c or d | a, b, c, or d |

**023. Fixed fire extinguishing installations in spaces containing internal combustion-type machinery**

(1) In all new ships a fixed fire extinguishing installation is to be provided for the protection of any space containing internal combustion-type machinery used for main propulsion, or having in the aggregate a total power of not less than 1,000 b.h.p. for auxiliary purposes. At least one of the fixed installations mentioned in paragraph 022(3) is to be provided as indicated below: —

New ships of 500 tons and over but less than 1,000 tons—a, b, c or d.

New ships of 1,000 tons and over—a, b or c.

(2) Existing motor ships not fitted with oil-fired auxiliary boilers are exempt from the requirements regarding fixed fire extinguishing installations in machinery spaces.

**024. Fixed fire smothering arrangements in cargo spaces of New Ships**

(1) All new ships of 2,000 tons and over are to be provided with a fixed fire smothering gas installation for the protection of every cargo space.

(2) The Regulations also permit a steam smothering system to be fitted in lieu of smothering gas, in which case the boiler or boilers available for supplying steam are to have an evaporation of at least 1 lb. of steam per hour for each 12 cu.ft. (1 kg. for each 0,75 cu.m.) of the gross volume of the largest cargo compartment. It is required that steam will be available immediately and will not be dependent on the lighting of boilers and that it can be supplied continuously until the end of the voyage in the required quantity *in addition* to any steam necessary for the normal requirements of the ship including propulsion and that provision is made for extra feed water necessary to meet this requirement.

This implies that an independent steam supply, together with additional feed water, is necessary if a steam smothering system is to be installed and, as this is not economical from the Owners' points of view, the use of this type of system in new ships has, so far, been avoided.

(3) In tankers a fixed installation discharging foam externally or internally to the tanks may be accepted as a suitable alternative to smothering gas.

(4) The requirements of the preceding paragraphs may be waived for the cargo holds of any ship, except for the tanks of a tanker: —

(a) If they are provided with steel hatch covers and effective means of closing all ventilators and other openings leading to the holds; or

(b) if the ship is constructed and employed solely in the carriage of bulk cargoes such as ore, coal or grain; or

(c) where the ship is engaged on voyages of such short duration that it would be unreasonable to apply the requirement.

**025. Fixed fire smothering arrangements in cargo spaces of Existing Ships**

(1) All existing ships of 2,000 tons and over are to be provided with a fixed fire extinguishing installation using steam or smothering gas for the protection of every cargo space. In tankers foam is acceptable as an alternative medium.

(2) Where smothering gas is used in dry cargo ships and foam in tankers, the requirements as for new ships are to be applied.

(3) Where a steam smothering system is installed, the available boilers are to be capable of evaporating 1 lb. of steam per hour for each 12 cu.ft. (1 kg. for each 0,75 cu.m.) of the gross volume of the largest hold or other cargo compartment capable of being effectively closed. Hatchway openings provided with wood covers and tarpaulins in accordance with the Load Line Rules, and 'tween deck bulkheads with tonnage openings closed by shifting boards or portable plates are accepted as compartment boundaries for this purpose.

The control cocks or valves are to be capable of being locked and are to be readily accessible from the weather deck, each control being clearly and permanently marked to indicate the compartment which it serves.

The piping is to be arranged so as to provide effective distribution of steam and, in any hold exceeding 60 ft. (18,3 m.) in length, two pipes are to be fitted, one in the forward part and one in the after part. In dry cargo spaces pipes for conveying steam are to be fitted with outlets as low as practicable and in tankers the piping is to be so arranged that steam will be distributed over the surface of the cargo.

(4) The requirements of the preceding paragraphs may be waived for the cargo holds of any ship, except in the tanks of a tanker, if one of the conditions described in paragraph 024(4) a, b or c has been met.

**026. Carbon dioxide gas fire extinguishing systems**

(a) When carbon dioxide is used as the extinguishing medium in cargo spaces, the quantity of gas available is to be sufficient to give a minimum volume of free gas equal to 30 per cent of the gross volume of the largest cargo compartment in the ship which is capable of being sealed. This applies to both new and existing ships.

(b) In new ships, when carbon dioxide is used as an extinguishing medium for spaces containing boilers or machinery, the quantity of gas carried is to be sufficient to give a minimum volume of free gas equal to the larger of the following, either: —

(i) 40 per cent of the gross volume of the largest space, the volume being measured up to the level at which the horizontal area of the casing is 40 per cent or less of the gross area of such space; or

(ii) 35 per cent of the entire volume of the largest space including the casing.

In ships of less than 2,000 tons, the above percentages may be reduced to 35 and 30 per cent respectively.

If two or more spaces containing boilers or internal combustion type machinery are not entirely separate they are to be considered as forming one compartment.

(c) In existing ships when carbon dioxide is used as an extinguishing medium for boiler rooms, the quantity of gas carried is to be sufficient to give a minimum volume of free gas equal to 30 per cent of the gross volume of the largest room measured to the top of the boiler. If the engine and boiler rooms are not entirely separate and fuel oil can drain from the boiler room into the engine room bilges, the combined engine and boiler rooms are to be considered as one compartment.

(d) When carbon dioxide is used as the extinguishing medium both for cargo spaces and for spaces containing boilers or machinery the quantity of gas need not be more than the maximum required either for the largest cargo compartment or machinery space.

(e) When calculating the amount of carbon dioxide required, one pound of liquid is capable of producing 9 cu.ft. of free gas or one kilogram will produce 0,56 cu.m.

(f) When carbon dioxide is used as the extinguishing medium for spaces containing boilers or machinery the fixed piping system is to be such that 85 per cent of the gas can be discharged into the space within two minutes.

(g) The gas cylinders and main controls are to be located in a cool and well ventilated position, not likely to be made inaccessible by an outbreak of fire in the space or spaces which they serve. Provision is to be made for the removal of the cylinders and checking their contents by weighing or other approved means. Operating instructions are to be displayed at the controls.

(h) Means are to be provided whereby audible warning is given automatically before fire smothering gas can be released into the machinery space and any other working space.

**027. Inert gas fire extinguishing systems for cargo spaces**

Where a generator producing inert gas is used to provide smothering gas in a fixed fire smothering system for cargo spaces, it is to be capable of producing hourly a volume of free gas at least equal to 25 per cent of the gross volume of the largest compartment protected in this way for a period of 72 hours. The generator is to be located in an accessible position and not likely to be cut off by an outbreak of fire in the compartments which it serves.

This type of gas generating plant, produces an inert gas composed of 85 per cent nitrogen, 14 per cent $CO_2$ and 1 per cent oxygen by burning diesel fuel oil in a carefully controlled quantity of air, but the gas generating rate is insufficient to deal with a machinery space fire, therefore its application is restricted to cargo compartments only.

**028. Fixed pressure water-spraying for machinery spaces**

(a) Fixed pressure water-spraying systems for boiler rooms with oil-fired boilers and engine rooms with internal combustion machinery are to be provided with a pump, piping system, control valves and spraying nozzles.

(b) The spraying nozzles are to be of such a type, sufficient in number and so arranged as to ensure distribution of water such as will effectively extinguish oil on fire in the spaces protected. Nozzles are to be fitted above bilges, tank tops and other areas over which oil fuel is liable to spread and also above oil-fuel settling and service tanks, heaters, pumping units, purifiers and other main fire hazards in the boiler and engine rooms.

(c) The water spraying system may be divided into sections and controlled from distribution manifolds capable of being operated from easily accessible positions outside the machinery spaces and which will not be readily cut off by an outbreak of fire.

(d) The system is to be kept charged at the necessary pressure and the pump supplying the water for the system is to be automatically put into action by a pressure drop in the system.

(e) The pump is to be capable of simultaneously supplying, at the necessary pressure, all sections of the system in any one compartment to be protected. The pump and its controls are to be installed outside the space or spaces to be protected. It is not to be possible for a fire in the space or spaces protected by the water spraying system to put the system out of action.

(f) Special precautions are to be taken to prevent the nozzles from becoming clogged by impurities in the water or corrosion of piping, nozzles, valves and pump.

(g) Operating instructions in clear and permanent lettering are to be affixed in a position adjacent to all controls connected with the water spraying system.

**029. Fixed froth fire extinguishing systems**

(a) In the case of new ships, the 1960 Regulations stipulate that any required fixed froth fire extinguishing system is to be capable of discharging a quantity of froth sufficient to cover a depth of 6 in. (150 mm.) the largest area over which oil fuel is liable to spread in the event of leakage.

(b) Such a system is to be controlled from an easily accessible position or positions, outside the space to be protected, which will not be readily cut off by an outbreak of fire.

(c) This requirement was intended for the protection of spaces containing internal combustion machinery or oil-fired boilers or oil burning equipment (*see* 022 and 023), but since its introduction, other methods of froth extinguishing have been contrived, such as high expansion froth systems which are capable of providing vast amounts of froth from relatively small quantities of water and froth concentrate. Methods of distributing froth over the entire deck area in way of the cargo tanks of oil tankers have also been devised. Whilst these new types of systems have been approved by the National Authorities in each individual case, the actual requirements are still under review at International level.

(d) In existing ships, the requirements of paragraph (a) and (b) are applicable, except in the case of motor ships having an auxiliary boiler in the engine room and the area over which oil fuel may spread is confined by coamings to less than 100 sq. ft. (9,29 sq.m.), the 6 in. (150 mm.) of froth required may be supplied from an extinguisher of not less than 30 gallons (135 litres) capacity. Similarly, where the area is small over which oil fuel may spread such as a unit, pump or fitting, froth to a depth of 6 in. (150 mm.) suitably restricted by coamings, may be provided by portable extinguishers; for this purpose an extinguisher of 2 gallons (9 litres) capacity is considered sufficient for about 5 sq.ft. (0,46 sq.m.).

**030. Means for stopping machinery and shutting off O.F. suction pipes**

(1) The following is applicable to new ships:—

(a) Means are to be provided for stopping ventilator fans serving machinery and cargo spaces also for closing all skylights, doorways, ventilators, funnel openings and other openings to such spaces. These means are to be capable of being operated from positions outside such spaces.

(b) Machinery driving forced and induced draught fans, oil fuel transfer pumps, oil fuel unit pumps and other similar fuel pumps are to be capable of being stopped by remote controls situated outside the space in which such machinery or pumps are situated.

(c) Every pipe connected to any oil fuel storage, settling or daily service tank, except a double bottom tank, which if damaged would permit discharge of the contents so as to cause a fire hazard, is to be fitted with a valve or cock secured to the tank and capable of being closed from a readily accessible position outside the space in which the tank is situated. In the case of deep tank outlets situated

in a shaft or pipe tunnel, a valve is to be fitted to the tank but control in the event of fire may be provided in the form of an additional valve fitted on the pipeline outside the tunnel.

(2) The following is applicable to existing ships:—

(a) Means are to be provided for stopping ventilator fans serving machinery and cargo spaces also for closing all skylights, doorways, ventilators, funnel openings and other openings to such spaces in which fire smothering gas or steam is used as an extinguishing medium.

### 031. Hydrants, hoses and nozzles outside machinery and boiler spaces

(a) In all ships, the number and position of the hydrants is to be such that at least two jets of water not emanating from the same hydrant, one of which being from a single length of hose, may reach any part of the ship normally accessible to the passengers or crew while the ship is being navigated. Furthermore, at least two jets of water must be able to reach any part of any cargo space when empty, but not necessarily from a single length of hose.

Hydrants on open decks are to be $2\frac{1}{2}$ in. (65 mm.) diameter, but where it can be shown that smaller hydrants provide the same quantity of water under the same conditions of pressure and nozzle size, consideration will be given to a reduction in the size of the hydrants. Alternatively, four jets from smaller hydrants may be accepted, but this will require at least twice the number of hoses normally provided.

Hydrants in accommodation spaces may be smaller to allow for the easier handling of the matching hose and there is much to recommend the provision of a small bore non-collapsible hose stored on a reel which has the water supply passing through the centre trunnion and thus enables one person to rapidly attack an outbreak of fire.

Each hydrant is to be fitted with a valve or cock and couplings of instantaneous, hermaphrodite or screw type may be used. Unless one hose and nozzle is provided for each hydrant in the ship there is to be complete interchangeability of hose couplings and nozzles. In ships which may carry deck cargo the fire hydrants are to be positioned so that they are always readily accessible and the possibility of damage by such cargo is to be avoided.

(b) Ships of 1,000 tons and upwards are to be provided with at least one fire hose for each 100 ft. (30 m.) length of ship and one spare hose, but in no case less than five in all. Smaller ships are to be provided with at least two fire hoses and one spare hose. This number is based on the length of each hose being 60 ft. (18,3 m.) and where shorter hoses are used, the number is to be proportionately increased, so that the aggregate length of hose is maintained. The number is not to be reduced when hoses of more than 60 ft. are used in special circumstances.

Furthermore, this requirement is based on the assumption that the fire hydrants are sufficient in number and suitably distributed so as to provide the necessary two jets of water, one being from a single length of hose in accommodation and service spaces and both from multiple lengths of hose in empty cargo spaces. Where necessary the number of hoses is to be increased according to the arrangements on board so as to ensure that this requirement is met.

Fire hoses are to be of seamless hemp, close weave flax canvas, or other approved material and are generally not to exceed 60 ft. (18,3 m.) in length, although there may be exceptions on large tankers and bulk carriers having clear deck areas where the use of longer hoses would not be too difficult. It must be borne in mind, however, that a $2\frac{1}{2}$ in. (65 mm.) hose filled with water is extremely heavy, fairly solid under pressure, and requires a great deal of effort to manipulate.

Each hose is to be provided with couplings to suit the hydrants and for joining the hose lengths together. The couplings are to be firmly secured to the hose by seizing wire or patent clips.

Each hose is to be provided with a nozzle having an outlet bore of not less than $\frac{1}{2}$ in. (12 mm.). For exterior locations $\frac{5}{8}$ in. (16 mm.) or $\frac{3}{4}$ in. (20 mm.) nozzles may be used so as to make full use of the maximum discharge capacity of the fire pumps and produce a powerful jet of water of at least 40 ft. (12,2 m.). Dual purpose nozzles for jet or fog-spray may be adopted.

Fire hoses, together with any necessary fittings and tools, are to be kept ready for use in conspicuous positions near the water service hydrants.

### 032. International shore connection

(a) All ships of 1,000 tons and over to be provided with at least one international shore connection to enable water to be supplied from the shore and arrangements are to be made so that the connection can be used on either side of the ship.

(b) The connection may be permanently installed on each side of the ship with an isolating valve or in the form of a portable fitting with an attached coupling that will fit the ship's hydrants. It is to have on one side a flat faced flange of steel or other material 9/16 in. (14,5 mm.) thick with dimensions as shown in Fig. 1, and suitable for a working pressure of 150 lb. per square in. (10,5 kg./cm.$^2$). Each connection on board is to be complete with a gasket, together with four $\frac{5}{8}$ in. (16 mm.) bolts each 2 in. (50 mm.) in length and eight washers.

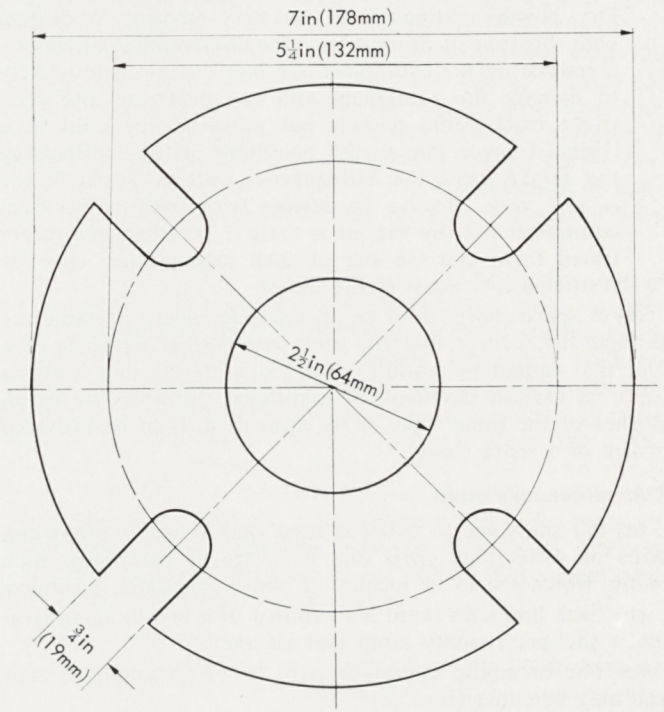



FIG. 1

**033. Portable extinguishers in accommodation and service spaces**

(a) All ships of 1,000 tons and over are to be provided with at least five portable extinguishers in any part of the accommodation and service spaces and smaller ships with not less than three such extinguishers.

(b) Consideration must be given, however, to the arrangements in each particular ship and, in general, one portable extinguisher is required in the vicinity of each accommodation entrance door with a minimum of one on each side of the ship at each deckhouse or superstructure tier.

(c) Protection is also to be provided for galleys or other spaces containing oil-fired ranges or heating boilers, the radio room or other spaces containing electrical equipment, in addition to accessible store rooms, paint room, carpenter's shop and similar compartments where a fire hazard exists.

(d) It is important that the most suitable type of extinguisher be available to fight the type of fire involved as indicated below:—

(A) Fires involving ordinary combustible materials such as wood, textiles, paper and furnishings. This type of fire is best extinguished by cooling, the most suitable extinguishing medium being water or solutions containing large percentages of water.

(B) Fires involving flammable liquids such as petrol, oils, paraffin, paints, varnishes, tar, greases and fats, which require a blanketing effect to prevent the supply of air necessary for combustion. Extinguishers discharging froth, dry powder or carbon dioxide are suitable for this purpose, but the latter type must not be used in confined spaces.

(C) Fires involving electrical equipment such as switch gear, radio installation, electric heaters and cooking apparatus, etc., where the use of a non-conducting extinguishing medium is essential due to the danger of electric shock. Dry powder extinguishers are very efficient in dealing with this type of fire but have the disadvantage of leaving a residue on the equipment. Carbon dioxide is less likely to damage the equipment and can penetrate into relatively inaccessible regions but must not be used in a confined space due to the possibility of gas suffocating the person using the extinguisher. Carbon Tetrachloride is also very effective in dealing with fires in electrical equipment but the vapour is toxic if breathed in concentrated form and the size of such extinguishers is to be restricted to 1 quart (1,136 litres).

(e) A spare charge is to be provided for every portable fire extinguisher, except that for each extinguisher which is of a type that cannot be readily recharged while the ship is at sea (such as carbon dioxide), an additional portable fire extinguisher of the same type, or its equivalent, is to be provided in lieu of a spare charge.

**034. Fireman's outfit**

(a) All ships are to carry at least one fireman's outfit and ships of 4,000 tons gross and over are to carry two such outfits which are to be located at widely separated positions.

(b) Each fireman's outfit is to consist of a breathing apparatus, a lifeline, a safety lamp and an axe.

(c) The breathing apparatus is to be of an approved type and may be either (i) or (ii):—

(i) A smoke helmet or smoke mask which is to be provided with a suitable air pump and a length of air hose sufficient to reach from the open deck, well clear of hatch or doorway, to any part of the holds or machinery spaces. If, in order to comply with this requirement, an air hose exceeding 120 ft. (36 m.) in length would be necessary, a self-contained breathing apparatus is to be substituted or provided in addition.

(ii) A self-contained breathing apparatus which is to be capable of functioning for a period of at least 30 minutes. Spare bottles are to be provided except where facilities for re-charging the bottles are available on board ship.

Each breathing apparatus is to have attached to its belt or harness, by means of a snaphook, a fireproof lifeline of sufficient length and strength.

(d) The safety lamp (hand lantern) is to be of an approved type. Such safety lamps are to be electric and are to have a minimum burning period of three hours.

(e) The axe is to have a short insulated handle, the head having a spike and a cutting edge, and the axe is to be complete with a carrying belt.

**035. Fire control plans**

(a) This requirement is applicable to new ships only.

(b) In all new ships a copy of the general arrangement plan of the ship is to be permanently displayed, for the guidance of the master and officers, showing clearly with the aid of colours and symbols, the position of the control stations for each deck, the sections of the ship which are enclosed by fire resisting and fire retarding bulkheads, together with particulars of the fire alarms, the fixed and portable fire extinguishing appliances and fireman's outfits, the means of access to the various compartments and decks in the ship, the ventilating system including particulars of the master fan controls, the position of dampers and identification numbers of the ventilating fans serving each section of the ship, the location of the international shore connection and the position of all means of stopping machinery, shutting off oil fuel suction pipes and closing of openings for the exclusion of air in the event of the outbreak of fire.

(c) The fire control plan is to be kept up-to-date and amendments or alterations are to be recorded at the time when they are executed.

**Life-saving appliances**

**036. Number and capacity of lifeboats and liferafts**

(1) Dry Cargo Ships

(a) All ships are to carry on each side of the ship one or more lifeboats of sufficient aggregate capacity to accommodate all persons on board and, in addition, are to carry liferafts of sufficient aggregate capacity to accommodate at least half the total number of persons on board.

(b) All new ships of 1,600 tons and over are to carry at least one motor lifeboat. In existing ships of this category a mechanically hand propelled lifeboat will be accepted in lieu of a motor lifeboat, but whenever any lifeboat requires to be renewed or replaced, a motor lifeboat is to be provided.

(c) All new and existing Liberian ships with no amidships superstructure having a registered length of 492 ft. (150 m.) and upwards are to carry, in addition to the liferafts mentioned in paragraph (1) (a), a liferaft capable of accommodating at least six persons which is to be stowed as far forward as is reasonable and practicable.

(2) TANKERS

(a) All tankers of less than 1,600 tons are to carry lifeboats and liferafts as required in paragraph (1) (a) for dry cargo ships.

(b) All tankers of 1,600 tons and upwards are to carry lifeboats on each side of the ship of sufficient aggregate capacity to accommodate all persons on board.

(c) All tankers of 3,000 tons and over are to carry four lifeboats. Two lifeboats are to be carried aft and two amidships, but in tankers having no amidships superstructure all four lifeboats are to be carried aft.

If, however, in tankers with no amidships superstructure, it is impracticable to carry four lifeboats aft, the Administration may permit the carriage of two lifeboats in lieu, subject to the following provisions:—

(i) Each lifeboat is not to exceed 28 ft. (8,5 m.) in length and is to be motor propelled (*see also* 2(e).

(ii) Each lifeboat is to be stowed as far forward as practicable, the minimum distance between the after end of the boats and the ship's propeller being one-and-a-half times the length of the lifeboat.

(iii) Each lifeboat is to be stowed as near the sea level as is safe and practicable.

(iv) Liferafts sufficient to accommodate at least half the total number of persons on board are to be carried in addition.

(v) All *new Greek* tankers of this category having a registered length of 492 ft. (150 m.) and upwards are to carry, in addition to the liferafts already required, a liferaft capable of accommodating at least 25 per cent of the total number of persons on board which is to be stowed as far forward as is reasonable and practicable.

(d) All new and existing *Liberian* tankers with no amidship superstructure and provided with either two or four lifeboats aft and having a registered length of 492 ft. (150 m.) and upwards are to carry, in addition to any other liferafts already required, a liferaft capable of accommodating at least six persons which is to be stowed as far forward as is reasonable and practicable.

(e) All new tankers of 1,600 tons and over are to carry at least one motor lifeboat on each side of the ship. In existing tankers of this category, one motor lifeboat will be accepted, but when any lifeboat requires to be renewed or replaced, a second motor lifeboat is to be provided.

(3) WHALE FACTORY, FISH PROCESSING AND CANNING FACTORY SHIPS

(a) All new ships engaged in these special duties and carrying persons, not being members of the crew, employed in the whaling, fish processing or canning industries are to carry:—

(i) Lifeboats on each side of the ship of sufficient aggregate capacity to accommodate one-half the total number of persons on board. Alternatively, the lifeboat capacity on each side may be reduced to a minimum of 37·5 per cent of the total number of persons on board but liferafts are to be provided so that the aggregate capacity of all lifeboats and liferafts is sufficient to accommodate all persons on board. The liferafts in this case are to be of a type capable of being launched with persons already in the raft.

(ii) Liferafts of sufficient aggregate capacity to accommodate at least half the total number of persons on board, in addition to the requirements of paragraph (a)(i).

(b) Every ship is to carry at least one motor lifeboat on each side.

(c) One lifeboat on each side of the ship is to be kept ready for immediate use in case of emergency while the ship is at sea. These lifeboats are not to exceed 28 ft. (8,5 m.) in length. The emergency boats, which may be either rowing or motor lifeboats, are to be capable of being quickly recovered and returned to their stowed positions on board.

(d) In the case of existing whale factory ships, the 1948 Regulations required lifeboats to be carried on each side of the ship of sufficient aggregate capacity to accommodate all members of the crew engaged to work the ship. Further lifeboats were required of a total capacity sufficient to accommodate the total number of additional persons carried but, if it was impracticable to attach these additional lifeboats to davits on account of limited space, they were allowed to be stowed below other lifeboats attached to davits.

Lifeboats which are not attached to davits are no longer permitted and should therefore be removed and the requirements as for new ships, including the carriage of liferafts, are to be applied.

(4) GENERAL REQUIREMENTS FOR LIFEBOATS

(a) In all ships of 1,600 tons and over, all lifeboats are to be not less than 24 ft. (7,3 m.) in length. Shorter boats may be carried in smaller ships but in no case is any lifeboat to be less than 16 ft. (4,9 m.) in length.

Special consideration will be given to existing ships of 1,600 tons and over where the lifeboats already provided are less than 24 ft. (7,3 m.) in length.

(b) The maximum permissible weight of any lifeboat complete with equipment and full complement of persons is 20 tons (20,300 kg.) and no lifeboat may carry more than 150 persons. All boats certified to carry more than 60 persons are to be motor lifeboats. It is, however, unlikely that large lifeboats will be encountered in cargo ships as, for example, a 250,000 tons deadweight tanker dealt with recently carries two motor lifeboats aft, each 26 ft. (7,9 m.) in length and of sufficient capacity to accommodate the total complement of only 44 persons.

(c) Occasions arise, particularly on existing ships, where the number of lifeboats carried are in excess of those required by the Regulations and Owners request that the surplus boats be excluded from the vessel's Safety Equipment and be marked accordingly. This procedure was general practice in the past but is now no longer permitted as, to carry a lifeboat which is not maintained and fitted out as a life-saving appliance could have disastrous results in the event of an emergency, especially if a defective lifeboat were to be launched during conditions of panic. Any lifeboat which is not required should therefore be removed from the ship or, if retained on board, is to be included in the Safety Equipment and maintained and equipped accordingly.

(d) Lifeboats constructed of wood, steel, aluminium alloy or glass reinforced plastic are accepted but the latter material is most popular for new lifeboats due to the comparatively simple method of construction and its non-corrosive properties.

(e) The dimensions of the lifeboat should be marked thereon in clear permanent characters. In the event of a boat having to be measured, the dimensions are ascertained as follows:—

Length—From the intersection of the outside of the planking or shell with the top of the stem to the corresponding point at the stern post, or in the case of a square-sterned lifeboat, to the after side of the top of the transom.

Breadth—From the outside of the planking or shell at the point where the breadth of the lifeboat is greatest.

Depth—Amidships inside the planking or shell from the keel to the level of the top of the gunwale.

(f) The cubic capacity of a lifeboat is the internal volume determined by Stirling's (Simpson's) Rule, which may be considered as given by the following formula:—

$$\text{Cubic capacity} = \frac{L}{12}(4A + 2B + 4C)$$

L denotes the length of the lifeboat from the inside of the shell at the top of the stem to the corresponding point at the top of the stern post. Where the boat has a square stern the length is measured to the inside of the top of the transom;

A, B, C, denote respectively the areas of the cross-sections at the three points obtained by dividing L into four equal parts. (The areas corresponding to the two ends are considered negligible.)

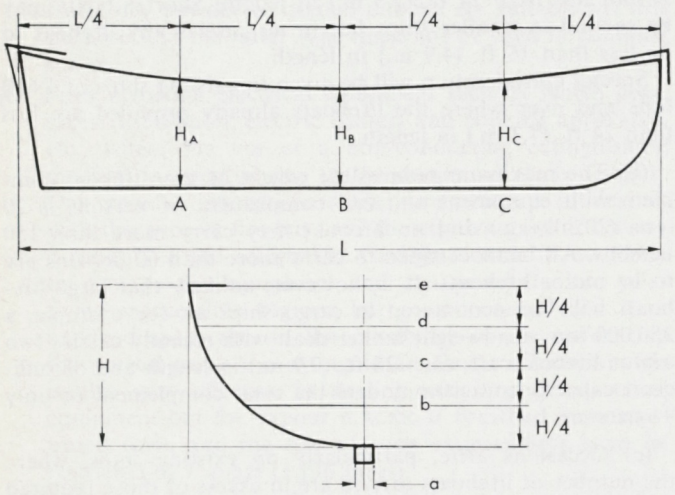



FIG. 2

The areas A, B, C are calculated by the successive application of the following formula to each of the three cross-sections:—

$$\text{Area} = \frac{H}{12}(a + 4b + 2c + 4d + e)$$

H being the depth from the inside the shell at the keel to the level of the gunwale or, in certain cases, to a lower level determined as follows:—

(i) The depth at amidships $H_B$ used in the calculation is not to exceed 45 per cent of the breadth of the boat.

(ii) The depths $H_A$ and $H_C$ employed in the calculation are not to exceed $H_B + \cdot 01L$.

In no case, however, are the depths used in the calculation to be greater than the actual depths as measured.

The cubic capacity of a lifeboat constructed of wooden planks may be assumed to be the product of $L \times B \times D \times 0{\cdot}6$ unless the owner of the boat requires the capacity to be determined by exact measurement and provided that the capacity obtained in this manner does not exceed that obtained by the formula using Simpson's Rule. The dimensions to be used are those described in paragraph (e).

The cubic capacity of a motor lifeboat or a lifeboat fitted with other propelling gear is to be obtained by deducting from the gross capacity a volume equal to the space occupied by the motor and its accessories or the gearbox of other propelling gear, also the radio installation and searchlight when such equipment is provided.

(g) The number of persons which a lifeboat is permitted to carry is equal to the greatest whole number obtained by dividing the net cubic capacity by x where L is the length of the boat:—

| L (feet) | L (metres) | x (feet) | x (metres) |
|---|---|---|---|
| 24 and over | 7,3 and over | 10 | 0,283 |
| 16 | 4,9 | 14 | 0,396 |

Intermediate values of x are to be obtained by interpolation.

The number of persons so calculated is not, however, to exceed that arrived at by allowing seating space of at least 18 in. (460 mm.) per person wearing a lifejacket and having sufficient leg room. The seating accommodation must also be arranged so that the seated persons do not interfere in any way with the use of the oars or the operation of other propulsion equipment.

(h) Every lifeboat is to be fitted with internal buoyancy in the form of either air cases or buoyant material which is not adversely affected by oil or oil products and which does not adversely affect the material of which the boat is constructed. Loose air cases in wooden or steel boats are to be constructed of copper or muntz metal and those in other metal boats are to be constructed of the same material as the boat.

In every lifeboat constructed in accordance with the requirements of the 1960 S.O.L.A.S. Convention, the total volume of the internal buoyancy is to be such that it will be at least equal to the sum of the volumes of:—

(i) That required to float the lifeboat and its full equipment when the lifeboat is flooded so that the waterline is level with the top of the gunwale amidships; and

(ii) That equal to one-tenth of the cubic capacity of the lifeboat.

The 1948 Convention required the total volume of the internal buoyancy of a wooden lifeboat to be at least equal to one-tenth of the cubic capacity of the boat. The buoyancy of lifeboats made of material other than wood was to be increased according to the additional weight of the boat.

All newly constructed lifeboats are to be built in compliance with the 1960 Regulations and existing boats will be accepted provided the 1948 Regulations have been met.

(5) REQUIREMENTS FOR MOTOR LIFEBOATS

In all new ships, motor lifeboats are to comply with the following:—

(a) A compression ignition engine is to be fitted which is to be capable of being readily started in cold weather and of

running reliably under conditions of extremes of temperature and under conditions of at least 10 degrees list and 10 degrees trim.

(b) The engine and its accessories, including the fuel tank, pipes and fittings, is to be adequately protected to ensure reliable operation under conditions likely to arise at sea during adverse weather. The engine casing is also to be fire-resisting and where air-cooled diesel engines are fitted it is essential to ensure that the supply of cooling air is not restricted.

(c) Means are to be provided to restrict the spread of oil and in a wooden boat a metal drip tray is to be fitted under the engine.

(d) Motor lifeboats carried on tankers, whale factory ships and fish processing or canning factory ships are to be capable of a speed of six knots going ahead in smooth water when loaded with a full complement of persons and equipment. Motor lifeboats carried on other cargo ships are to be capable of a speed of four knots under the same conditions and all motor lifeboats are to be capable of going astern.

(e) Each motor lifeboat is to be provided with sufficient fuel for 24 hours continuous running at the speed specified in the foregoing paragraph. One type of air cooled diesel engine used consumes approximately ·05 gallons (·227 litres) per hour for each continuous h.p. whilst running at full load at 2,000 rev./min. A 20 h.p. engine of this type would therefore require approximately $20 \times \cdot 05 \times 24 = 24$ gallons or $20 \times \cdot 227 \times 24 = 110$ litres of fuel for 24 hours continuous running. Technical data provided by the engine manufacturers enables the actual amount of fuel to be determined in each particular case.

The fuel tank is to be substantially constructed, securely fixed in position with a metal tray underneath and provided with suitable filling and venting arrangements. Soft solder is not to be used in the tank seams or connections and steel tanks are to be protected externally against corrosion by metal spraying or similar means. The tank and its connections are to be capable of withstanding a test pressure of 5 lb. per square in. (0,35 kg./cm.$^2$). A cock is to fitted at each end of the fuel pipe.

Guards are to be fitted over the shafting and other moving parts to protect persons in the lifeboat from possible injury.

(f) In existing ships lifeboats fitted with spark-ignition engines and petrol fuel will be accepted whilst the engines remain in efficient condition. When however, a petrol-driven engine requires to be renewed or replaced a compression-ignition engine complying with the 1960 Regulations for new ships is to be installed.

(6) Requirements for mechanically propelled lifeboats

Under the 1948 Regulations, a lifeboat driven by hand mechanically propelled gear was acceptable as being equivalent to a motor lifeboat but this is no longer applicable. This type of lifeboat is now only acceptable on new ships in lieu of a rowing boat.

Such lifeboats are to be capable of being propelled at a speed ahead of at least 3·5 knots in smooth water over a distance of $\frac{1}{4}$ mile (463 m.) and the gear is to be capable of being operated by untrained persons and when the boat is flooded. Provisions are to be made whereby the helmsman can cause the lifeboat to go ahead or astern at any time when the propelling gear is in operation.

**037. Stowage and handling of lifeboats**

(a) Every lifeboat is to be attached to a set of davits and is to be capable of being launched with the ship listed to 15 degrees either way and with a 10 degrees trim. Lifeboats are not to be stowed in the bows of the ship and are to be so situated to ensure safe launching having particular regard to clearance from the propeller and steeply overhanging portions of the hull aft and to ensure so far as is practicable that they can be launched down the straight side of the ship.

(b) A lifeboat which can be lowered with its full complement of persons, except emergency boats of whale factory, fish processing and canning factory ships, is to be fitted with skates to facilitate launching against an adverse list. Vertical skid bars are to be provided in way of ship's side openings and tapered skid chocks fitted in way of belting or other projections where the boat is liable to foul during launching.

(c) Lifeboats are to have falls ready for service and the falls are to be at least long enough to reach the water with the ship at her lightest sea-going draught and listed to 15 degrees either way. The lower fall blocks are to be fitted with a suitable ring or long link to provide for the speedy, but not necessarily simultaneous, release of the boat from the falls. Alternatively, an approved type of disengaging gear may be fitted, in which case, the lifting hooks are to be released simultaneously from a control position at the aft end of the boat. The disengaging gear is to be such that it will permit release under a towing strain on the link or falls and the hooks are to be suitable for the instant release of the long link by hand in an emergency. The lifeboat lifting hooks are to be sufficiently high above the gunwale as to ensure stability when the fully loaded boat is being lowered.

(d) Where the lifeboats are served by wire rope falls, winches fitted with a brake are to be provided for controlling the lowering of the boats and emergency boats on whale factory, fish processing and canning factory ships are to be served by winches which are capable of recovering them at a speed of not less than 60 ft. (18,28 m.) per minute when the boat is loaded with its equipment and a distributed load of 2,240 pounds (1016 kg.).

Where the lifeboats are served by manila falls in existing ships and winches are not provided, the lowering is to be controlled by hand by leading the rope over a bollard. Such an arrangement is not suitable for lowering the boat with a full complement of persons and a notice is to be displayed to indicate that the lifeboat is to be lowered with the launching crew only. This also applies in the case of existing ships fitted with davits which are not strong enough to lower the fully laden boats.

(e) When the lifeboats are stowed they are to be secured by gripes which can be quickly released from inboard. Chafing plates are to be fitted to the gunwale and care must be taken to ensure that the boat is protected against chafing by the gripe wires or any other part of the gear when stowed. Slip links and hemp lashings for cutting in an emergency are to be provided in readily accessible positions to enable the gripes to be quickly released.

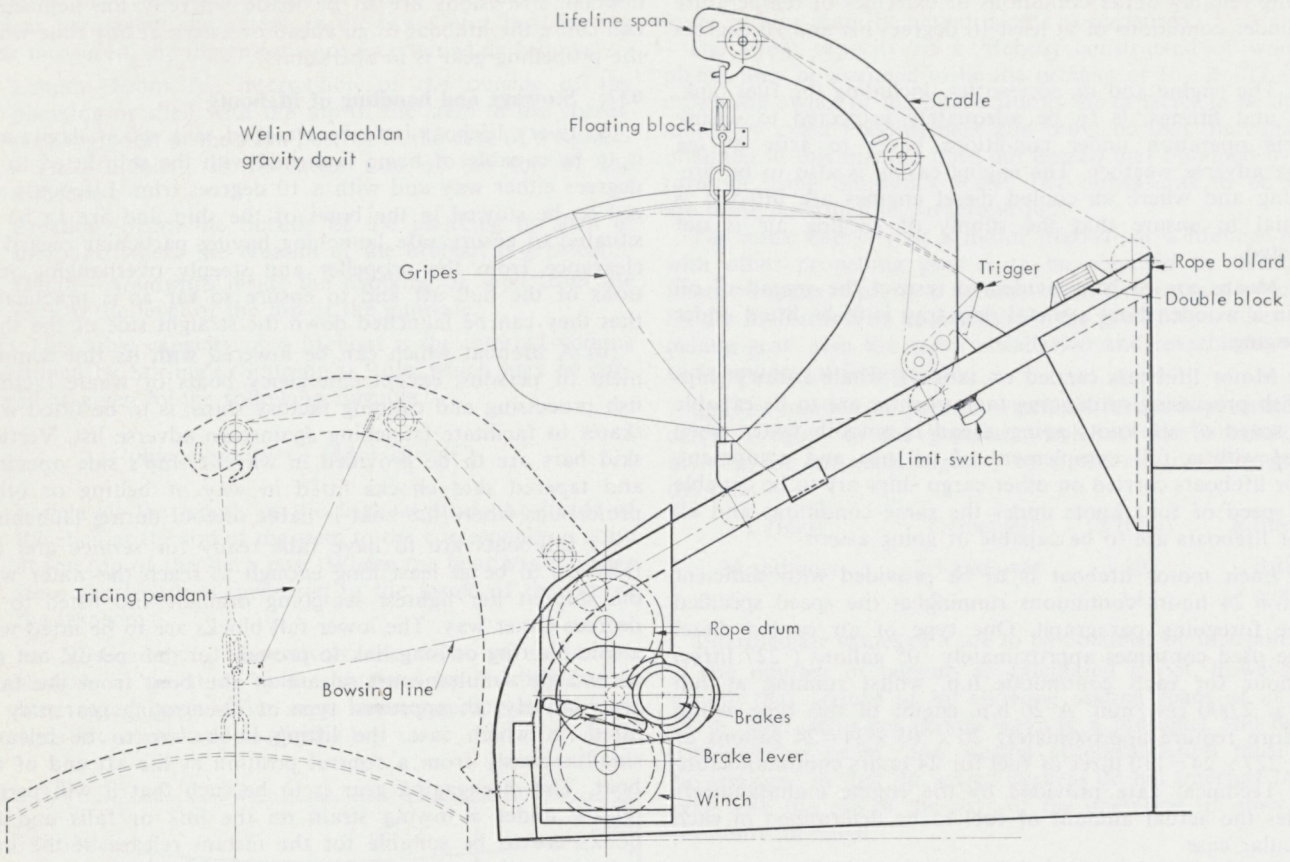



FIG. 3

**038. Davits and launching gear**

(a) In new tankers of 1,600 tons and upwards, new whale factory, fish processing and canning factory ships the davits are to be of the gravity type. In other new ships, gravity type davits are to be fitted, except that where the lifeboats weigh not more than 2·25 tons (2300 kg.) in their turning out condition, davits of the luffing type may be installed.

(b) All gravity davits are required to have a positive turning out moment during the whole of the davit travel from the inboard to the outboard position when the ship is upright and also when the ship is listed to any angle up to and including 25 degrees either way from upright.

(c) The operating gear of all luffing type davits is to be of sufficient power to ensure that the fully equipped lifeboats manned by a launching crew of two persons can be turned out against a list of at least 15 degrees.

(d) Davits, falls, blocks and other associated lowering gear are to be of such strength that the lifeboat with its full equipment and manned by a launching crew of not less than two persons can be turned out and then safely lowered to the water from the embarkation position with its full complement of persons, when the ship has a trim of up to 10 degrees and a list of 15 degrees either way. The weight of each person is to be taken at 165 lb. (75 kg.).

(e) Lifeboats attached to gravity type davits are to be served by wire falls and winches. The breaking tensile load of each wire rope fall is to be not less than six times the maximum load on the wire when lowering, hoisting or stowing. The winch is to be fitted with a drum for each wire so as to keep the two falls separate and a hand brake, in addition to an automatic brake, is to be provided for controlling the lowering speed of the boat. The hand brake is to have a weighted hand control lever which, when lifted, allows the winch to rotate and when released operates the brake effectively without having to apply additional pressure. The automatic brake is to be adjusted to give a lowering speed of between 60 and 120 ft. (18 to 36 m.) per minute.

(f) Winches are to be provided with an efficient hand gear for the recovery of the lifeboats and where davits are recovered by the action of the falls by power, an automatic cut-out is to be installed to prevent the gear being overstressed when the davits meet with the stops.

(g) Lifeboats attached to luffing type davits are also to be served by wire rope falls and winches under the same provisions as for gravity davits except that the Regulations allow for manila falls, where the Administration is satisfied that such falls are adequate. Details of all lifeboat launching arrangements are to be submitted for approval.

(h) Some relaxation is permitted in existing ships, including tankers, of over 150 ft. (46 m.) in length, laid down on or after 19.11.52, in that luffing type davits are acceptable for operating lifeboats weighing not more than 4 tons (4064 kg.) in their turning out condition: for heavier boats gravity type davits only are permitted. The requirements for the strength

of the davits and gear, provision of wire falls, winches and other equipment are the same as those now applicable to new ships.

In existing ships, including tankers not exceeding 150 ft. (46 m.) in length, laid down on or after 19.11.52 and in all ships irrespective of length laid down before that date, radial type davits are acceptable with manila rope falls for lowering the boats.

Whenever it is necessary to renew a set of davits on an existing ship the replacements are to comply with the 1960 Regulations as for new ships.

### 039. Liferafts

The carriage of inflatable or rigid type liferafts as part of the Safety Equipment in dry cargo ships and certain types of tankers became mandatory when the 1960 S.O.L.A.S. Convention came into force and the relevant requirements apply to both new and existing ships irrespective of age. All liferafts carried are to be constructed in accordance with the 1960 Regulations.

An inflatable liferaft is to have a carrying capacity of not less than six and not more than 25 persons and the total weight of the raft complete with equipment and its valise or other container is not to exceed 400 lb. (180 kg.). It is to be so constructed that if dropped into the water from a height of 60 ft. (18 m.) neither the liferaft nor its equipment will be damaged. The liferaft is to be inflated by a gas which is not injurious to the occupants and the inflation is to take place automatically on the pulling of a line or an equivalent simple and efficient method.

A rigid liferaft may only exceed 400 lb. (180 kg.) in weight if it is capable of being launched from both sides of the ship or if launching arrangements are provided for conveying it to the water mechanically. It is to be so constructed that if dropped into the water from its stowed position neither the raft nor its equipment will be damaged and is to be at all times effective and stable when floating either way up.

All liferafts are to be readily available in case of emergency and are to be capable of being conveyed to the water safely and rapidly even under unfavourable conditions of trim and of up to 15 degrees of list either way. They are to be stowed so as not to interfere with the operation of the lifeboat launching arrangements.

Inflatable and rigid liferafts which are manufactured in a 1960 Convention country and approved by the National Authorities under the provisions of the Convention are generally acceptable but it should be noted that only two rigid type liferafts are approved by the Liberian Authorities namely (1) "The Floating Igloo" manufactured by Walter Tangen, and (2) The "Glafi" liferaft, by Einar Elvrum, both these rafts being of Norwegian manufacture.

### 040. Embarkation into lifeboats and liferafts

(a) Arrangements are to be made to ensure that it is possible to effect embarkation into the lifeboats and liferafts rapidly and in good order.

(b) A ladder is to be carried at each set of davits and at each liferaft stowage position to afford access to the lifeboats and liferafts when waterborne. Where approved mechanical devices are provided for lowering persons into boats and rafts, at least one ladder is to be carried on each side of the ship.

(c) Each set of lifeboats davits is to be fitted with a wire rope span and at least two fibre rope lifelines not less than 3 in. (75 mm.) in circumference, knotted at intervals of about 24 in. (610 mm.), and long enough to reach the water with the ship at its lightest sea-going draught and listed to 15 degrees either way.

(d) New ships provided with lifeboats which are capable of being lowered in the fully loaded condition are to be provided with bowsing gear at each davit to hold the boat against the ship's side at the embarkation deck level to enable persons to be safely embarked. The gear is to be controlled by the launching crew in the boat and capable of quick release prior to lowering the boat to the water. Where davits are of the gravity type, an additional single wire tricing pendant is necessary in order to stop the boat at the correct level prior to bowsing in. The tricing pendant is to be set up at the lower end with a slip to enable it to be rapidly cast off.

(e) When pump discharges are at or below the lightest sea-going waterline or where the pumps are out of action when the propelling machinery is stopped, no objection is taken to the stowage of lifeboats or liferafts abreast these discharges. When, however, the discharges of independent pumps which may be operating under emergency conditions are situated higher up on the ship's side, and if lifeboats or liferafts are stowed abreast these discharges, then means are required for stopping the pumps from positions outside the engine room to ensure that when the boats and rafts are lowered they will not be swamped by water from the discharges. The positions of pump discharges and particulars of the pump to which they are connected are to be indicated on the plans of boat stowage when these are submitted for approval.

In existing ships, if means of stopping the necessary pumps are not provided, hoods of steel or heavy reinforced rubber, fitted to the shell over the discharge openings to deflect the water down the ship's side will be accepted as an alternative. Deflectors of a portable nature such as plates or boards suspended over the discharges are not acceptable.

(f) A muster list is to be drawn up before the ship sails and is to show the special duties undertaken by each member of the crew in the event of an emergency and is to indicate, in particular, the station to which each member must proceed and the duties that he has to perform. The list is to be displayed in several parts of the ship, particularly in the crew's quarters.

The muster list is to detail the duties assigned to members of the crew in connection with the closing of watertight doors, valves and closing mechanisms of scuppers, fire doors, the conveyance of the portable radio apparatus, the preparation of life-saving appliances, the muster of passengers, the launching of lifeboats and liferafts and the extinction of fire. The list is also to specify definite signals for calling all the crew to their boat, liferaft and fire stations.

A muster of the crew for fire and boat drills is to take place at intervals not exceeding one month when the boats' equipment is to be verified and if more than 25 per cent of the crew have been replaced, drills are to take place within 24 hours of leaving port in order to fully acquaint the personnel with the fire extinguishing and life-saving arrangements.

Different lifeboats are to be used in turn at successive boat drills and every lifeboat is to be turned out at least once every four months and lowered to the water whenever practicable. Every opportunity should be taken to try motor lifeboats under running conditions afloat. The musters and

inspections are to be so arranged that the crew thoroughly understand and are practised in duties they have to perform.

The date upon which musters are held is to be recorded in the ship's log book and, if in any month no muster or a part muster only is held, an entry is to be made stating the circumstances and extent of the muster carried out. A report of the examination of the boats' equipment is to be entered in the log book which is also to record the occasions when the lifeboats are turned out and lowered to the water.

(g) Arrangements are to be made for the transmission of the signals specified in the muster list for calling the crew to their lifeboat and liferaft stations if and when the ship is about to be abandoned and to the fire stations in the event of an outbreak of fire. The warning signals, which are to be audible throughout the ship whilst under way with the main and auxiliary machinery running, are to be made on the ship's whistle and, in new ships of 150 ft. (45,7 m.) in length and over, are to be supplemented by electrically activated alarm bells or similar signals operated from the bridge.

(h) Electric lighting powered by the ship's main generating plant is to be provided:—

(i) In all ships for the illumination of the lifeboats and liferaft stowage positions during the preparation for and the process of launching and also for lighting the water into which the lifeboats, and the liferafts served by launching appliances, are launched.

(ii) In new ships of 1,600 tons and upwards for lighting the alleyways, stairways and exits so as to ensure that access of all persons on board to the launching stations and stowage positions of liferafts is not impeded.

In new ships only, this lighting is also to be capable of being supplied for a specified period by the emergency source of power described in paragraph 041.

**041. Emergency source of electric power**

(a) This requirement applies to *new ships only*.

(b) All new ships are to be provided with a self-contained source of electric power, situated in a position above the uppermost continuous deck and outside the machinery casings and so arranged as to ensure its functioning in the event of fire or other casualty causing failure of the main electrical installation.

(c) The emergency source of power may be either, accumulator (storage) batteries capable of carrying the emergency load without being recharged or suffering an excessive voltage drop, or a generator driven by internal combustion type machinery with an independent fuel supply, the flash point of the fuel being not less than 110°F (43°C).

The emergency source of power is to be capable of functioning when the ship has a list of 22½ degrees either way and a trim of 10 degrees.

Provision is to be made for the periodical testing of the emergency source of power and its associated circuits.

(d) Where applicable, the emergency source of power is to be capable of operating the following services simultaneously for the continuous period specified:—

(1) The illumination of the lifeboats and liferaft stowage positions during the preparation for and the process of launching and also for lighting the water into which the lifeboats, and the liferafts served by launching appliances, are launched.

(2) The lighting of alleyways, stairways and exits so as to ensure that access of all persons on board to the launching stations and stowage positions of liferafts is not impeded.

(3) The lighting of the main machinery space, the space containing the ship's main electric generating plant the navigating bridge and chartroom.

(4) The general alarm, if electrically operated.

(5) The ship's navigation lights if solely electric; and

(6) The daylight signalling lamp if it is operated only by the ship's main source of electric power.

(e) The requirements described in the foregoing paragraph (d) are to be applied as follows:—

(i) In ships of 5,000 tons and over, all the items (1) to (6) for a continuous period of not less than six hours.

(ii) In ships of 1,600 tons and over but under 5,000 tons, items (1), (2), (4), (5) and (6) for a continuous period of not less than three hours.

(iii) In ships of under 1,600 tons, items (1), (4), (5) and (6) for a continuous period of not less than three hours.

**042. Lifejackets**

(a) One lifejacket of an approved type is to be provided for every person carried on the ship.

(b) Lifejackets filled with kapok or equally effective buoyant material may be carried on all ships and each such lifejacket is to be designed so that it is capable of supporting 16½ lb. (7,5 kg.) of iron for 24 hours in fresh water.

(c) Lifejackets which depend upon inflated air compartments for buoyancy may also be carried on all ships *except tankers* and each such lifejacket is to have two separate air compartments, each capable of supporting 16½ lb. (7,5 kg.) of iron for 24 hours in fresh water. The lifejacket is to be capable of being inflated both mechanically and by mouth.

(d) An inflatable lifejacket having only one air compartment inflated and a lifejacket of the kapok type is to comply with the following requirements:—

(i) The design is to eliminate, as far as possible, all risk of it being put on incorrectly but it is to be capable of being worn inside out.

(ii) It is to be capable of turning the wearer, on entering the water, to a safe floating position with the body inclined backwards and of supporting the head of an unconscious person so that the face is held above the water.

(iii) It is to be of a highly visible colour, fitted with a non-corrosive whistle attached by a lanyard and is not to be adversely affected by oil or oil products.

(e) Lifejackets are to be stowed in readily accessible places either in cabins or in clearly marked and well ventilated boxes or lockers on deck near the lifeboats and liferafts.

**043. Lifebuoys**

(a) In all ships not less than eight properly becketed lifebuoys are to be carried.

(b) Each lifebuoy is to be 18 in. (460 mm.) inside diameter and of solid cork or other equally efficient buoyant material which is not adversely affected by oil or oil products and is to be capable of supporting 32 lb. (14,5 kg.) of iron for 24 hours in fresh water. It is to be of a highly visible colour and clearly marked in block letters with the name and port of registry of the ship in which it is carried.

(c) Lifebuoys filled with rushes, cork shavings, granulated cork or any other loose granulated material, or which are dependent upon inflated air compartments for buoyancy are prohibited, and those made of plastic or other synthetic compounds are to be capable of retaining their buoyant properties and durability in contact with sea water or oil products, or under variations of temperature or climatic changes prevailing in sea voyages.

(d) Two lifebuoys are to be positioned on the wings of the navigating bridge, in quick release chutes, each provided with a self-activating smoke signal capable of producing smoke of a highly visible colour for at least 15 minutes, and a self-igniting light.

(e) At least two lifebuoys are to be provided with self-igniting lights and where more than eight lifebuoys are carried, at least half the additional lifebuoys are also to be provided with self-igniting lights.

(f) One lifebuoy on each side of the ship is to be fitted with a buoyant lifeline at least 15 fathoms (27,5 m.) in length. These lifebuoys are not to have lights attached and should be located on the lowest working deck so as to be as close to the water as possible.

(g) The self-igniting lights are to be such that they cannot be extinguished by water and are to be capable of burning for not less than 45 minutes with a luminosity of not less than 3·5 lumens. Lights carried on tankers are to be of the electric battery type.

(h) All lifebuoys are to be capable of being rapidly cast loose and are not to be permanently secured in any way. Spare or other lifebuoys kept in stores or lockers are not to be included in the Safety Equipment and are not to be mentioned in the Rpt. SE1.

**044. Pilot ladders**

All ships are to be provided with a pilot ladder complying with the following requirements:—

(a) The ladder is to be efficient and is to be used only by officials and other persons while the ship is arriving at or leaving a port, and for the safe embarkation and disembarkation of pilots.

(b) The pilot ladder is to be secured in a position clear of any possible discharges from the ship with each step resting firmly against the ship's side so that the pilot can gain convenient access to the ship after climbing not less than 5 ft. (1,5 m.) and not more than 30 ft. (9 m.).

(c) A single length of ladder is to be used capable of reaching the water from the point of access to the ship when the ship is in an unloaded condition and in normal trim. Whenever the distance from the water to the point of access to the ship exceeds 30 ft. (9 m.), access from the pilot ladder to the ship is to be by means of an accommodation ladder or other equally safe and convenient means.

(d) The treads of the ladder are to be of hardwood not less than 19 in. (48 cms.) long, $4\frac{1}{2}$ in. (11,4 cms.) wide and 1 in. (2,5 cms.) in depth, spaced not less than 12 in. (30,5 cms.) and not more than 15 in. (38 cms.) apart and secured in such a manner that they will remain horizontal. The side ropes of the ladder are to consist of two manila ropes each $2\frac{1}{4}$ in. (57 mm.) in circumference.

(e) Hardwood spreaders about 6 ft. (1,8 m.) long are to be provided at intervals of 8 to 10 ft. (2,4 to 3,0 m.) to prevent the ladder twisting or alternatively, every eighth step should be about 6 ft. (1,8 m.) long.

(f) A man-rope, properly secured to the ship and a safety line are to be available and ready for use if required.

(g) Means are to be provided to enable the pilot ladder to be used on either side of the ship and to enable the pilot to pass safely and conveniently from the head of the ladder into the ship or on to the ship's deck.

(h) A light is to be provided at night so that the pilot ladder overside and also the postion where the pilot embarks or disembarks is adequately illuminated.

(i) The rigging of pilot ladders and the embarkation and disembarkation of pilots is to be supervised by a responsible officer of the ship.

(j) Where fenders or other projections make it impracticable for the pilot ladder steps to rest firmly against the ship's side, the arrangements will be specially considered.

**045. Lights and sound signals**

Every ship issued with a Safety Equipment Certificate must comply with the International Regulations for Preventing Collisions at Sea which require that all power driven vessels of 65 ft. (19,8 m.) or more in length are to carry one or two masthead lights according to the length of the ship, two side lights, one stern light, two "not-under-command" lights, and one or two anchor lights according to the ship's length. The lights to be carried by ships of less than 65 ft. (19,8 m.) in length, fishing vessels, ships engaged on underwater operations or surveying duties, sailing ships, pilot vessels, tugs, trawlers and othe craft are also specified in the Collision Regulations.

The length and breadth of a ship referred to in the Collision Regulations means the overall length and extreme breadth.

All power driven ships of 65 ft. (19,8 m.) or more in length are to be provided with navigation lights as follows:—

(a) SIDE AND MASTHEAD LIGHTS

(i) On the port side a red light and on the starboard side a green light, both arranged to show an unbroken light from right ahead to $22\frac{1}{2}$ degrees abaft the beam and visible at a distance of two miles.

(ii) On or in front of the foremast, or in the fore part of the ship, a white light arranged to show an unbroken light from right ahead to $22\frac{1}{2}$ degrees abaft the beam on both sides and visible at a distance of five miles. The height above the uppermost continuous deck is to be at least 20 ft. (6,10 m.) but need not exceed 40 ft. (12,20 m.). Where, however, the breadth of the ship is between 20 ft. (6,10 m.) and 40 ft. (12,20 m.), the height is to be not less than the breadth.

(iii) On ships of 150 ft. (45,75 m.) or more in length, a second white light similar to the first, which may be placed on the main mast or other suitable position at least 15 ft. (4,57 m.) higher than the forward light and so that the horizontal distance between the two white lights is not less than three times the vertical distance between them.

The Collision Regulations are a present under review by I.M.C.O. as, whilst the requirements have proved to be adequate in the past, ships are now sailing the high seas whose length and heading cannot always be properly deduced from

the positioning of the navigation lights. The following recommendations have so far been made and, whilst these do not yet apply internationally, they were adopted by the Republic of Liberia on the 1st July, 1970:—

(1) Vertical positioning of masthead lights.

The vertical distance between the masthead lights should be such that in all normal conditions of trim the aft light will be seen over and apart from the fore light at a distance of 1,000 m. from the stem when viewed from sea level.

(2) Positioning of side lights.

The side lights should be positioned at a height not greater than three-quarters of the height of the fore light above the uppermost continuous deck. They should not be low enough to be interfered with by deck lights. On horizontal positioning, they should not be fitted in front of the fore light. They should also be situated at or near the ship's side.

(3) Horizontal separation of masthead lights.

Horizontal separation of foremast and mainmast light should be not less than one-half of the total length of the ship, and the fore light should not be more than one-quarter of the ship's length from the stem.

The above recommendations should be borne in mind in the case of all new large ships and a plan showing the Shipbuilders' proposals should be submitted to London Office for consideration.

(b) Stern light

At the stern of the ship, as far aft as possible, a white light arranged to show an unbroken light from right astern to $22\frac{1}{2}$ degrees abaft the beam on both sides of the ship and visible at a distance of two miles.

(c) Anchor lights

(i) Ships of less than 150 ft. (45,75 m.) in length, when at anchor, are to carry in the forepart of the vessel where it can best be seen, a white light visible all round the horizon at a distance of at least two miles.

(ii) In ships of 150 ft. (45,75 m.) or more in length, a second white light similar to the first is to be carried at or near the stern and both lights are to be visible at a distance of three miles. The forward light is to be at least 20 ft. (6,10 m.) above the uppermost continuous deck and the after light not less than 15 ft. (4,57 m.) lower than the forward light.

(d) Not-under-command lights

In a position where they can best be seen, a power-driven vessel not under command is to carry two red lights in a vertical line one above the other not less than 6 ft. (1,83 m.) apart, visible all round the horizon at a distance of two miles.

(e) Screening of sidelights

Oil and electric side lanterns are to be provided with screens not less than 36 in. (910 m.) in length forward of the flame of an oil lamp, or the filament of an electric lamp, with a screening chock at the forward end projecting outboard, to prevent the light from being seen across the bows. The breadths of the screening chocks of oil and electric lights on each side are to be recorded on the Rpt. SE1.

(f) Spare electric lamps

A stock of at least one complete set of spare electric lamps of the correct type is to be carried. Lamps should be of the vacuum type having the cylindrical "squirrel cage" form of filament. Gas filled lamps should not be used.

(g) Carriage of oil lanterns

In all ships where the navigation lights are powered only by the ship's main electric generating plant, provision is to be made so that the ship can display the required lights in the event of complete failure of the main source of power. Compliance with this requirement can be achieved by providing a complete set of oil lanterns having the same characteristics as those applicable to electric lights. If, however, the ship is to berth at ports or oil installations, refineries, etc., where the lighting of oil lanterns is prohibited by local bye-laws, a duplicate arrangement of electric lights and their source of power is required. The secondary power in new ships is to be supplied from the emergency source described in paragraph 041 and in existing ships a similar arrangement is required except that the secondary source of power may be situated in the engine room.

**046. Signalling apparatus**

(a) Daylight signalling lamp

All ships over 150 tons engaged on international voyages are to be provided with an efficient electric type daylight signalling lamp which may be battery operated and may also be adapted to enable the current to be derived from the ship's mains. In new ships, the signalling lamp is not to be solely dependent upon the ship's main source of electrical power and secondary power is to be provided either from an independent battery or the emergency source described in paragraph 041.

(b) Sound signals

All power-driven ships are to be provided with the following signals for use in restricted visibility:—

(i) An efficient bell hung in the fore part of the ship clear of all obstructions having a diameter of not less than 12 in. (305 mm.) at the mouth, except in ships under 150 ft. (47,75 m.) in length where a bell 8 in. (203 mm.) is acceptable.

(ii) An efficient fog-horn sounded by mechanical means. Fog-horns of the rotary and crank-bellows type are the most efficient at present in use. Plunger type fog-horns are not usually efficient but may be accepted if found to be entirely satisfactory. Horns blown by mouth are not acceptable.

(iii) In ships of more than 350 ft. (106,75 m.) in length, a gong for use at the after end of the ship. The tone of the gong is to be such that it cannot be confused with the sound of the bell and for this purpose a mild steel gong not less than 16 in. (406 mm.) diameter with a lip of 2 in. (50 mm.) is the most suitable instrument.

(iv) An efficient whistle operated by steam or other means located so that the sound cannot be intercepted by any obstruction and well clear of, and above, deck houses, ventilators, etc. The whistle should be audible for a distance of two miles in undisturbed atmosphere.

(c) Daylight shapes

(i) All ships are to carry three black ball shapes each not less than 2 ft. (610 mm.) in diameter. Three are to be displayed when the ship is aground, two when not under command and one in the fore part of the ship when at anchor, between sunrise and sunset. When more than

one are shown they are to be placed in a vertical line one above the other, not less than 6 ft. (1,83 m.) apart where they can best be seen.

(ii) All ships are to carry a black diamond shape at least 2 ft. (610 mm.) in diameter which is to be displayed where it can best be seen when the vessel is being towed and the length of the tow exceeds 600 ft. (183 m.).

**047. Lifeboat equipment**

All lifeboats in new and existing ships are to be equipped in accordance with the requirements of Regulation 11, Chapter III of the 1960 S.O.L.A.S. Convention. All items of equipment, with the exception of the boat hook which is to be kept free for fending off purposes, is to be suitably secured within the boat. The lashing is to be carried out in such a manner as to ensure the security of the equipment and so as not to interfere with the lifting hooks or to prevent ready embarkation. All items of equipment are to be as small and as light in weight as possible and packed in suitable and compact form. All rations are to be stowed in watertight tanks which are to be firmly secured to the lifeboat.

Each lifeboat is to be provided with the following equipment: —

(1) Two crutches (one each side) at each rowing thwart attached by lanyard or chain and one spare crutch for each rowing thwart. Crutches are to be of galvanised wrought iron, of uniform pattern and interchangeable for use in any position and with any oar. If thole pins are used, one set of thole pins is equivalent to one crutch.

(2) Two plugs for each plug hole in the bottom of the boat, attached by lanyards or chains. Plugs are not required where automatic valves are fitted. The position of each plug hole should be clearly indicated on the inside of the boat so that it may be readily located.

(3) Rudder and tiller. Means are to be provided to prevent the rudder from being accidentally dislodged and wherever possible, the rudder is to be kept shipped in place while the lifeboat is in the stowed position.

(4) A lifeline of 2 in. (50 mm.) manila or sisal rope, becketed around the outside of the boat from stem to stern and secured below the rubber at intervals of not more than 24 in. (610 mm.), having full loops reaching within 3 in. (75 mm.) of the water line when the boat is fully loaded.

(5) Bilge keels or keel rails, together with not less than two grablines, to enable persons to cling to the boat should it be upturned. The lines are to be secured from gunwale to gunwale under the keel and knotted at intervals to form hand grips and are also to have loops positioned at the keel for the support of the arm.

(6) A manually operated bilge pump fitted with suction and delivery hoses for transferring water over the side. The pump is to be permanently secured in position and capable of being readily opened for cleaning and examination without the use of special tools. If the boat is divided into wells arrangements are to be made for pumping out each well.

(7) A suitable locker for the stowage of small items of equipment.

(8) Two painters of sufficient length having regard for the height of the deck above the light water line and the possibility of a list. One is to be firmly secured to the stem and the other secured forward with a toggle through an eye splice which enables it to be readily slipped.

(9) Two light buoyant heaving lines, each about 10 fathoms (18,2 m.) long and about 1 in. (25 mm.) in circumference.

(10) For every pulling lifeboat a single banked complement of oars, i.e. one oar for each rowing thwart and for every motor or mechanically propelled lifeboat only half the complement is required with a minimum of four oars. The length of an oar varies according to the length of the boat and is usually not less than 12 ft. (3,66 m.) and not more than 16 ft. (4,88 m.). Pulling oars should be stowed fore and aft along the side-benches, half the number on the port side, half on the starboard, with their blades forward.

(11) Two spare rowing oars for each pulling boat only. Spare oars are not required on motor or mechanically propelled lifeboats.

(12) One steering oar for every lifeboat. The steering oar is to be at least 12 in. (305 mm.) longer than the pulling oars and its blade should be painted white to distinguish it from the other oars. It should be stowed with the blade aft.

Provision is to be made for housing the steering oar either by a crutch secured to the gunwale or a grummet fastened to the stern post.

(13) One boat hook for each pulling lifeboat and two for each motor lifeboat and mechanically propelled boat.

A boat hook is to be not less than 8 ft. (2,44 m.) long and 2 in. (51 mm.) in diameter at mid-length.

(14) Each pulling lifeboat is to be fitted with a wood mast supported by galvanised wire rope stays and one set of sails. The length of the mast is usually about 0·6 the length of the boat but should be long enough to allow the sails to be set well clear of the thwarts. The mast is to be fitted with a head band of sufficient strength to take the halyard blocks and rigging placed so as to allow ample hoist for the mainsail. The stays should be set up with hemp lashings to plates secured to the gunwale about 2 ft. (610 mm.) abaft the mast.

The lifeboat sails comprising a lugsail with yard and a jibsail, are to be coloured orange. The mainsail is to be marked for identification purposes with the first and last letter of the name of the ship to which the lifeboat belongs. The letters, of white material sewn on the canvas on both side in the middle of the sail, should not be less than 2 ft. (610 mm.) high and 3 in. (76 mm.) thick. Motor lifeboats and mechanically propelled lifeboats need not be provided with a mast or sails.

(15) A cover of highly visible colour capable of protecting the the occupants against injury by exposure.

The cover should extend from the stem head to within about 5 ft. (1,5 m.) of the stern so as to provide coverage for about 80 per cent of the length of the lifeboat. The cover should be arranged from gunwale to gunwale, supported by suitable framework erected on the boat, extending below the gunwale on the outside about 6 in. (150 mm.) with a suitable means of fastening, such as ties on the inside which can be quickly released in case of emergency. Ties should also be provided on the inside of the cover at the centre-line and sides to secure it in position on the framework. Provision is also to be made

to enable the sides of the cover to be rolled up and tied off for ventilation and for rowing purposes whilst still giving overhead protection to the occupants of the lifeboat.

The cover may be of cotton canvas about 8 to 10 oz. per square yard (270 to 340 grms per sq. m.) weight and waterproofed, or of a suitable flexible synthetic material such as vinyl coated nylon or terylene of equivalent strength. Particular attention should be paid to the chafing qualities of the material used.
The cover is to be coloured "rescue" orange on the outside and it is recommended that the inner surface be coloured grey/green or a light grey shade to reduce the orange glare penetration, particularly where synthetic material is used.

The framework may be of light gauge tubing in aluminium alloy or galvanised mild steel and arranged in the form of hoops spaced about 4 ft. (1,2 m.) apart, with wire ridges if necessary. Each hoop is to be shipped into a socket arrangement at the sides of the boat, preferably with a support on the side benches. The hoops may be fitted with hinged joints or be telescopic provided they are rigid when erected and no sharp corners or edges exist which could cause damage to the cover.
Consideration will be given to other forms of cover and framework provided the cover is set up by simple methods to create a "stressed skin" arrangement whilst retaining the main features described.

(16) 2 lb. (1 kg.) of provisions for each person the lifeboat is certified to carry. The provisions are to be packed in air-tight receptacles stowed in watertight containers and may be either (a) biscuits, (b) an approved ration such as Dutch or Scandinavian, or (c) biscuits and barley sugar in equal quantities.

(17) 1 lb. ($\frac{1}{2}$ kg.) of condensed milk for each person the lifeboat is certified to carry, stowed in watertight containers.

(18) 6 pints (3 litres) of fresh water for each person the lifeboat is certified to carry, kept in the lifeboat in suitable containers. If plastic containers are used to carry the drinking water, they are to be robustly constructed of dark green material, not coloured by painting, and provided with screw caps fitted with brass chain attachments.

NOTE.—Occasions arise on existing ships where the lifeboat capacity is substantially in excess of crew requirements and Owners request that the quantity of lifeboat provisions be reduced accordingly. In such cases, where only one lifeboat is carried on each side, provisions for all persons on board the ship may be accepted as complying with the Regulations. This does not apply to water, since the question of upkeep does not arise and there is no reason why water tanks should not be filled to capacity.

It is necessary, however, in cases of this nature, to change the marking of the boat to indicate that it should carry only the number of persons for which provisions are supplied, i.e. the physical capacity of the boat permits the carriage of 80 persons and 60 persons are on board the ship, rations for 60 persons may be supplied in the lifeboat provided the boat is marked for a capacity of 60 persons.

(19) One set of distress signals comprising four red parachute signals, six red hand flares and two buoyant smoke signals.

(20) One baler not less than 8 in. (203 m.) in diameter with lanyard.

(21) Two plastic or galvanised buckets with lanyards, each about 2 gallons (9 litres) capacity. One to be stored forward and one aft.

(22) Two single-edged hatchets having good cutting edges, attached by lanyards and readily available, one at each end of the boat.

(23) A lamp containing sufficient oil to burn 12 hours and capable of burning in a strong wind. The lamp, showing an all-round white light should be constructed of brass, copper or other suitable material with the glass suitably caged for protection and of a size that will fit conveniently into one of the buckets.

(24) Two boxes of matches not readily extinguished by wind, in a watertight container.

(25) An efficient compass in binnacle, luminised or provided with means of illumination. A boat's compass is a "liquid compass", the bowl being filled with a low-freezing compound, usually a mixture of industrial methylated spirit and distilled water. The compass card should not be less than 4 in. (100 mm.) in diameter.

(26) A sea anchor which is used to keep the boat head-on to the wind and sea when weather conditions preclude sailing. The sea anchor is a cone-shaped canvas bag about 4 ft. (1,2 m.) in length with a mouth about 27 in. (685 mm.) in diameter with a hawser three times the length of the boat attached to the mouth and a tripping line about 2 fathoms (3,66 m.) longer than the hawser secured to the point.

(27) One gallon ($4\frac{1}{2}$ litres) of animal, vegetable or fish oil for use in the oil bag.

(28) One storm oil canvas bag with two lanyards, one for attaching the bag to the sea anchor hawser and the other for sealing the mouth of the bag when in use. In bad weather, the bag, containing a quantity of storm oil, is attached to the sea anchor hawser and punctured in several places to allow oil to flow to the surface and thus prevent seas breaking on board and swamping the boat.

(29) One rustproof dipper with lanyard for use with the fresh water containers.

(30) One rustproof graduated drinking vessel or beaker.

(31) One approved first aid outfit in a watertight case and effectively sealed.

(32) One electric hand torch which can be used for Morse Code signalling together with one spare set of batteries and one spare bulb in a waterproof container.

(33) One daylight signalling mirror (heliograph).

(34) One jack-knife with a tin opener kept attached to the lifeboat by a lanyard.

(35) One whistle or reed-horn to give a clear audible signal.

(36) One set of fishing tackle comprising a line and six hooks.

(37) One copy of the illustrated table of life-saving signals.

(38) One short ladder, suitably weighted, or other means to enable persons in the water to climb into the upright lifeboat.

(39) Two hand fire extinguishers are to be carried in motor lifeboats only.

(40) The dimensions of a lifeboat and the number of persons which it is permitted to carry is to be marked thereon in clear permanent characters. The name and port of registry of the ship to which the lifeboat belongs is to be painted on each side of the bow.

**048. Portable radio apparatus**

All ships are to carry an approved portable radio apparatus for use in survival craft which is to include a transmitter, a receiver, an aerial and a power supply preferably derived from a hand generator. The apparatus is to be watertight, buoyant and of robust construction enabling it to be dropped overboard without damage. The unit should be not more than 31 lb. (14 kg.) in weight and as compact as practicable.

On new ships the apparatus is to be capable of transmitting and receiving on 500 kc/s. which is the international distress frequency for radiotelegraphy and on 2182 kc/s., the international distress frequency for radiotelephony. Transmission is also required on 8364 kc/s. which is the frequency used to establish communications relating to the safety of life at sea and used by survival craft stations during search and rescue operations. Facilities for automatic and manual transmissions on frequencies of 500 kc/s. and 8364 kc/s. are to be provided including a device for the generation of the radiotelephone alarm signal on 2182 kc/s.

On existing ships the apparatus is to be capable of the transmitting and receiving on 500 kc/s. and also of transmitting on 8364 kc/s. with facilities for automatic and manual transmissions.

The portable radio equipment is to be kept in the chart room, radio room or other suitable place where it will be readily available in an emergency, but in tankers of 3,000 tons and upwards where lifeboats are carried amidships and aft the equipment is to be kept in the vicinity of the lifeboats which are furthest away from the main transmitter.

**049. Rigid liferaft equipment**

All rigid liferafts in new and existing ships are to be equipped in accordance with the requirements of Regulations 16 and 17, Chapter III of the 1960 S.O.L.A.S. Convention and the equipment is to be readily available whichever way up the liferaft is floating.

Each rigid liferaft is to be provided with the following equipment:—

(1) One attached painter.

(2) Lifeline becketed around the outside of the raft.

(3) Lifeline fitted around the inside of the liferaft.

(4) Two sea anchors, one permanently attached to the liferaft and one spare complete with line.

(5) One buoyant battery type light attached by a lanyard.

(6) 12 oz. (340 grams) of suitable non-thirst provoking food for each person the liferaft is certified to carry.

(7) 6 oz. (170 grams) of barley sugar or other equally suitable sweets for each person the liferaft is certified to carry.

(8) Watertight receptacles containing 3 pints ($1\frac{1}{2}$ litres) of fresh water for each person the liferaft is certified to carry.

(9) Six anti-seasickness tablets for each person the liferaft is certified to carry.

(10) Two paddles.

(11) One approved first aid outfit in waterproof case.

(12) Two red parachute signals.

(13) Six red hand flares.

(14) One buoyant rescue quoit attached to 100 ft. (30 m.) of buoyant line.

(15) One knife and one baler for rafts fit to accommodate not more than 12 persons.

(16) Two knives and two balers for rafts fit to accommodate 13 persons or more.

(17) Two sponges for mopping up water and moisture inside the raft.

(18) One repair outfit for repairing punctures in buoyancy compartments, if applicable.

(19) Three tin (can) openers.

(20) One rustproof graduated drinking vessel.

(21) One waterproof electric torch suitable for Morse Code signalling with one spare set of batteries and one spare bulb in a waterproof container.

(22) One daylight signalling mirror (heliograph).

(23) One signalling whistle.

(24) One set of fishing tackle comprising a line and six hooks.

(25) Instructions on how to survive in the liferaft.

(26) One copy of the illustrated table of life-saving signals.

(27) Every rigid liferaft is to be marked with the name and port of registry of the ship in which it is carried, and with the number of persons it is permitted to carry.

**050. Inflatable Liferafts**

Liferafts of the inflatable type are to contain the equipment required for rigid liferafts with the addition of a topping-up pump or bellows.

Such liferafts should only be opened for internal examination by an Authorised Agent of the Manufacturer and not by the Surveyor. The Manufacturer's Agent is to provide a certificate of examination stating that the liferaft and its equipment complies with Regulations 15 and 17, Chapter III of the 1960 S.O.L.A.S. Convention.

The valise or container of each inflatable liferaft is to be clearly marked with the number of persons the raft is certified to carry.

# ANNEX I

## DUTCH REGULATION FOR SEAGOING SHIPS BELOW 500 TONS GROSS

### Life-saving appliances

(1) Every ship of this category shall carry either:—

A lifeboat on each side of the ship (minimum length 4,9 m.) of sufficient capacity to accommodate all persons on board and in addition, one or more (if the crew consists of more than ten persons at least 2) liferafts of sufficient aggregate capacity to accommodate all persons on board; or

One or more inflatable or rigid liferafts on each side of the ship of sufficient aggregate capacity to accommodate all persons on board and in addition, a rescue boat of approved type. (This does not apply to tankers or ships carrying cargoes the vapours of which cause liferafts to deteriorate, e.g. chemical tankers, etc.)

NOTE.—Prior to 1965, ships of less than 250 tons gross were permitted to carry one lifeboat which could be launched on either side of the ship by a derrick and in addition, one liferaft. The existing arrangements in such ships continue to be accepted.

(2) The rescue boat required under (1) may be either:—

A boat which may be square-sterned with minimum dimensions $4{,}20 \times 1{,}70 \times 0{,}68$ m., or

A dinghy having minimum dimensions $4{,}30 \times 1{,}60 \times 0{,}65$ m., or

An approved rubber inflatable boat, minimum dimensions 3,70 m. long $\times$ 1,60 m. breadth, stowed on board permanently inflated, clear of the deck and in a protected position. The air pressure is to be regularly checked and an air pump is to be readily available for topping-up purposes. A painter not less than 15 m. long is to be attached to each end of the boat for launching purposes.

(3) Equipment of Lifeboats.

The normal equipment of every lifeboat shall consist of:—

A single banked complement of buoyant oars (one per rowing thwart), two spare buoyant oars, one set (two) per thwart as well as one-half set of thole pins or crutches should be attached by lanyard or chain.

One boat hook.

Attached rudder with tiller.

One painter of sufficient length secured forward with strop and toggle.

Two plugs for each plug hole with lanyard or chain.

One baler, one bucket and one hatcher.

One sea anchor with oil bag and $4\frac{1}{2}$ litres storm oil.

One foghorn.

Four red parachute distress signals, six red hand flares and two buoyant smoke signals.

One waterproof electric torch suitable for Morse signalling together with one spare set of batteries and one spare bulb in waterproof container.

One daylight signalling mirror.

One jack-knife with tin opener secured to boat by lanyard.

One 30 m. buoyant heaving line fitted with buoyant quoit.

Three fishing lines with hooks.

A food ration comprising $\frac{1}{2}$ kg. approved rations for each person the boat is certified to carry.

2 litres of fresh water, in watertight receptacles for each person the boat is certified to carry.

An approved first aid outfit in a watertight case.

A rustproof dipper.

A rustproof graduated drinking vessel.

A set of wooden splints.

A copy of the illustrated table of life-saving signals.

A lifeline becketed around the outside of the boat.

Two grablines secured from gunwale to gunwale under the keel, together with bilge rails to enable persons to cling to the boat should it be upturned.

Skates required when the boat deck is more than 15 ft. above the deepest loadline.

The inside of the boat to be painted orange and the name and port of registry of the ship to which the boat belongs to be painted on each side of the bow.

A box containing repair material for the boat (nails, rubber, piece of aluminium plate, etc.).

(4) Equipment of inflatable and rigid liferafts.

Two sea anchors with 9 m. line, one permanently attached one spare.

One baler, two sponges and one jacknife; two balers and two jack-knives if raft carries more than 12 persons.

One topping-up pump or bellows (inflatable rafts only).

One throwing line with buoyant quoit, length 100 ft. (or 30 m.).

Two paddles.

Two red parachute distress signals and six red hand flares.

One waterproof electric torch suitable for Morse signalling with one spare set of batteries and one spare bulb in waterproof container.

One daylight signalling mirror and one whistle.

One set of fishing tackle.

A food ration comprising $\frac{1}{2}$ kg. approved rations per person.

$1\frac{1}{2}$ litres of fresh water for each person in watertight receptacles.

One rustproof graduated drinking vessel.

Three safety tin openers.

Six anti-seasickness tablets for each person the raft is certified to carry.

A waterproof instruction book on how to survive in the raft.

An approved first aid outfit in a watertight case.

A copy of the illustrated table of life-saving signals.

Material for repairs of inflatable liferaft compartments, 3 stoppers of different sizes and material for permanent repairs of inflatable and rigid liferafts.

NOTE.—On ships provided with liferafts, two waterproof notices illustrating the upkeep and handling of the rafts are to be posted in conspicuous places on board (e.g. messrooms). Also one instruction book on the handling of liferafts should be available on board.

(5) Rigid rescue boat equipment.

One oar per thwart (minimum 2 oars) and one set of thole pins or crutches attached by lanyard or chain.

One boat hook.

One rudder with tiller.

One painter of sufficient length firmly secured to stem.

Two plugs per plug hole attached by lanyard or chain.

One baler.

Six red hand flares and one whistle.

One waterproof electric torch.

One 30 m. buoyant heaving line fitted with buoyant quoit.

(6) Inflatable rescue boat equipment.

Four paddles.

One sea anchor with 30 ft. (or 9 m.) line.

One buoyant heaving line fitted with buoyant quoit.

One baler.

One topping-up pump or bellows.

Six red hand flares.

One waterproof electric torch.

One whistle.

An outfit for repairing punctures in buoyancy compartments.

(7) Lifebuoys.

Ships less than 18 m. shall carry one lifebuoy. Ships from 18 to 45 m. shall carry 3 lifebuoys, of which 2 should be with self-igniting light attached by a lanyard.

Ships from 45 to 91 m. shall carry 4 lifebuoys, of which 2 should be with self-igniting light attached by a lanyard.

The lifebuoys may be of the circular or horse-shoe type with beckets securely seized and marked with the ship's name and port of registry.

(8) Lifejackets.

One approved lifejacket with whistle to be provided for each person carried on board.

**Fire Appliances**

(1) Fire hoses and nozzles.

On ships having propelling machinery of 160 h.p. or more, at least one fire hose 15 to 20 m. but of a maximum length of 25 m. is to be provided in addition to any hose for wash-deck purposes. The fire hose should be able to reach all parts of the ship and should be provided with a combined jet-spray nozzle (dia. min. 12 mm.).

Hose and nozzle should be stowed in a box, or on a reel painted red.

Ships having propelling machinery of less than 160 h.p. are to be provided with fire buckets.

(2) Fire-fighting equipment.

All portable fire extinguishers are to be of a type approved by the Dutch Shipping Inspectorate, the capacity not more than 13,5 and not less than 9 litres and same should be painted red, whilst the contents should be suitable for oil fires.

The following are to be provided:—

ENGINE ROOM (internal combustion or gas turbines).

Below 160 h.p.: one extinguisher.

160–below 300 h.p.: two extinguishers.

Above 300 h.p.: three extinguishers.

ACCOMMODATION

Usually from three to five extinguishers (of which one in galley) are required.

One additional foam extinguisher is required if an oil fired central heating boiler is installed.

Small extinguishers are to be provided outside radio-telephone or telegraphy installations (2 kg.) suitable for fires in electrical equipment.

Spare charges for extinguishers to be provided.

One large fire axe of approved type to be provided.

(3) Oil or chemical tankers and carriers of similar products of less than 500 tons gross (K-1 and K-2 cargoes, flashpoint below 55°C) are also to be provided with *two* sets of the following fire-fighting equipment:—

Approved breathing apparatus.

Fire proof and lifeline with snaphooks.

Approved safety lamp.

Fire axe of approved type.

(4) The breathing apparatus may consist of the following:—

Smoke helmet with hose (long enough to reach each part of the ship without buckling the hose, but not more than 36 m. in length), with bellows or airpump, or self-contained oxygen or compressed air apparatus for at least 45 minutes operation.

Spare oxygen bottle and calcium cartridge or spare compressed air bottle.

**Other Equipment**

(a) At least 12 red parachute distress signals.

(b) Approximately 50 litres of storm oil depending on length of ship.

(c) One approved safety lamp.

(d) An alarm signalling device for abandoning ship controlled from the bridge powered by batteries or other emergency source.

(e) One day signalling lamp.

(f) One pilot ladder of sufficient length.

ANNEX II

# Cargo Ship Safety Equipment Report

Port.....

Date.....

| Name of Ship | Signal Letters | Port of Registry | Gross Tonnage |
|---|---|---|---|
| | | | |

## This is to Certify that

I. The above-mentioned ship has been duly inspected in accordance with the provisions of the International Convention for the Safety of Life at Sea, 1960.

II. The inspection showed that the life-saving appliances provided for a total number of.....persons and no more viz.:—

.....lifeboats on port side capable of accommodating.....persons;

.....lifeboats on starboard side capable of accommodating.....persons;

.....motor lifeboats (included in the total lifeboats shown above), including.....motor lifeboats fitted with radiotelegraph installation and searchlight, and.....motor lifeboats fitted with searchlight only;

.....liferafts, for which approved launching devices are required, capable of accommodating .....persons; and

.....liferafts, for which approved launching devices are not required, capable of accommodating .....persons;

.....lifebuoys;

.....lifejackets.

III. The lifeboats and liferafts were equipped in accordance with the provisions of the Regulations annexed to the Convention.

IV. The ship was provided with a line-throwing apparatus and portable radio apparatus for survival craft in accordance with the provisions of the Regulations.

V. The inspection showed that the ship complied with the requirements of the said Convention as regards fire extinguishing appliances and fire control plans and was provided with navigation lights and shapes, pilot ladder, and means of making sound signals and distress signals, in accordance with the provisions of the Regulations and the International Collision Regulations.

VI. In all other respects the ship complied with the requirements of the Regulations so far as these requirements apply thereto.

This inspection has been carried out under the authority of the Swedish Government.

The undersigned declares that he is duly authorised by the said Government to carry out the inspection hereby reported.

.....

Surveyor to Lloyd's Register of Shipping

ANNEX III

# Cargo Ship Safety Equipment Certificate

## THE REPUBLIC OF LIBERIA

*Issued under the provisions of the*

INTERNATIONAL CONVENTION FOR THE SAFETY OF LIFE AT SEA, 1960

| Name of Ship | Distinctive Number or Letters | Port of Registry | Gross Tonnage | Date on which keel was laid *See note below* |
|---|---|---|---|---|
| "SPECIMEN I" | 5LSJ | MONROVIA | 112763 | 1969 |

**I, the undersigned,** **certify**

I That the above-mentioned ship has been duly inspected in accordance with the provisions of the Convention referred to above.

II That the inspection showed that the life-saving appliances provided for a total number of 44 persons and no more, viz.:—

1 lifeboats on port side capable of accommodating 44 persons;

1 lifeboats on starboard side capable of accommodating 46 persons;

2 motor lifeboats (included in the total lifeboats shown above), including – motor lifeboats fitted with radiotelegraph installation and searchlight, and – motor lifeboats fitted with searchlight only;

– liferafts, for which approved launching devices are required, capable of accommodating persons; and

2 liferafts, for which approved launching devices are not required, capable of accommodating 31 persons; including one 6 man liferaft forward

8 lifebuoys;

44 lifejackets.

III That the lifeboats and liferafts were equipped in accordance with the provisions of the Regulations annexed to the Convention.

IV That the ship was provided with a line-throwing apparatus and portable radio apparatus for survival craft in accordance with the provisions of the Regulations.

V That the inspection showed that the ship complied with the requirements of the said Convention as regards fire-extinguishing appliances and fire control plans and was provided with navigation lights and shapes, pilot ladder, and means of making sound signals and distress signals, in accordance with the provisions of the Regulations and the International Collision Regulations.

VI That in all other respects the ship complied with the requirements of the Regulations so far as these requirements apply thereto.

**This Certificate is issued under the authority of the Government of the Republic of Liberia.**

**It will remain in force until** ..... 19.....

**Issued at** ..... the ..... day of ..... 19.....

The undersigned declares that he is duly authorised by the said Government to issue this Certificate.

.....

Surveyor to
Lloyd's Register of Shipping
Authorised Agent of the Republic of Liberia

NOTE:—It will be sufficient to indicate the year in which the keel was laid except for 1952 and 1965, in which cases the actual date should be given.

SEST (LIB) 15m,3,68 (MADE AND PRINTED IN ENGLAND)

# LLOYD'S REGISTER OF SHIPPING

## Cargo Ship Safety Equipment Certificate

KINGDOM OF GREECE

*Issued under the provisions of the*

INTERNATIONAL CONVENTION FOR THE SAFETY OF LIFE AT SEA, 1960

| Name of Ship | Distinctive Number or Letters | Port of Registry | Gross Tonnage | Date on which keel was laid |
|---|---|---|---|---|
| "SPECIMEN II" | SYZM | PIRAEUS | 6718 | 1957 *See note below* |

I, the undersigned, certify

I. That the above-mentioned ship has been duly inspected in accordance with the provisions of the Convention referred to above.

II. That the inspection showed that the life-saving appliances provided for a total number of 40 persons and no more, viz.:—

1 lifeboats on port side capable of accommodating 46 persons;

1 lifeboats on starboard side capable of accommodating 50 persons;

* motor lifeboats (included in the total lifeboats shown above), including – motor lifeboats fitted with radiotelegraph installation and searchlight, and – motor lifeboats fitted with searchlight only;

– liferafts, for which approved launching devices are required, capable of accommodating ... persons; and

2 liferafts, for which approved launching devices are not required, capable of accommodating 20 persons;

8 lifebuoys;

46 lifejackets.

*One mechanically propelled lifeboat included in the total lifeboats shown above.

III. That the lifeboats and liferafts were equipped in accordance with the provisions of the Regulations annexed to the Convention.

VI. That the ship was provided with a line-throwing apparatus and portable radio apparatus for survival craft in accordance with the provisions of the Regulations.

V. That the inspection showed that the ship complied with the requirements of the said Convention as regards fire-extinguishing appliances and fire control plans and was provided with navigation lights and shapes, pilot ladder, and means of making sound signals and distress signals, in accordance with the provisions of the Regulations and the International Collision Regulations.

VI. That in all other respects the ship complied with the requirements of the Regulations so far as these requirements apply thereto.

This certificate is issued under the authority of the Greek Government.

It will remain in force until ..... 19.....

Issued at ..... the ..... day of ..... 19.....

The undersigned declares that he is duly authorised by the said Government to issue this Certificate.

.....

Surveyor to Lloyd's Register of Shipping

71, Fenchurch Street, London, E.C.3.

NOTE:—It will be sufficient to indicate the year in which the keel was laid except for 1952 and 1965, in which cases the actual date should be given.

15m,8,66

ANNEX V

# Certificate of Cargo Ship Safety Equipment Survey

Port.....

Date.....

| Name of Ship | Distinctive Number or Letters | Port of Registry | Gross Tonnage |
|---|---|---|---|
| | | | |

This is to certify that the safety equipment of this ship has been surveyed at the request of the Government of ....., in the manner prescribed in the Regulations annexed to the International Convention for the Safety of Life at Sea 1960, and that the provisions of these Regulations, as regards safety equipment, have been complied with.

A. The inspection showed that the life-saving appliances provided for a total number of..... persons and no more, viz.:—

.....lifeboats on port side capable of accommodating.....persons;

.....lifeboats on starboard side capable of accommodating.....persons;

.....motor lifeboats (included in the total lifeboats shown above), including.....motor lifeboats fitted with radiotelegraph installation and searchlight, and.....motor lifeboats fitted with searchlight only;

.....liferafts, for which approved launching devices are required, capable of accommodating .....persons; and

.....liferafts, for which approved launching devices are not required, capable of accommodating .....persons;

.....lifebuoys;

.....lifejackets.

B. The lifeboats and liferafts were equipped in accordance with the provisions of the Regulations.

C. The ship was provided with a line-throwing apparatus and portable radio apparatus for survival craft, in accordance with the provisions of the Regulations.

D. The inspection showed that the ship complied with the provisions of the Regulations as regards fire extinguishing appliances and fire control plans and was provided with navigation lights and shapes, pilot ladder, and means of making sound signals and distress signals, in accordance with the provisions of the Regulations and the International Collision Regulations.

E. In all other respects the ship complied with the requirements of the Regulations so far as these requirements apply thereto.

This certificate remains effective until..... 19.....

Issued at.....the.....day of..... 19.....

.....
Surveyor to Lloyd's Register of Shipping

CONDITIONAL ISSUE ANNEX VI

Cert. SEST

# LLOYD'S REGISTER OF SHIPPING

## Cargo Ship Safety Equipment Certificate

REPUBLIC OF PANAMA

*Issued under the provisions of the*

INTERNATIONAL CONVENTION FOR THE SAFETY OF LIFE AT SEA, 1960

| Name of Ship | Distinctive Number or Letters | Port of Registry | Gross Tonnage | Date on which keel was laid |
|---|---|---|---|---|
| "SPECIMEN III" | HPWI | PANAMA | 3331 | 3.12.52 *See note below* |

**I, the undersigned,** certify

I. That the above-mentioned ship has been duly inspected in accordance with the provisions of the Convention referred to above.

II. That the inspection showed that the life-saving appliances provided for a total number of 39 persons and no more, viz.:—

1 lifeboats on port side capable of accommodating 39 persons;

1 lifeboats on starboard side capable of accommodating 40 persons;

1 motor lifeboats (included in the total lifeboats shown above), including – motor lifeboats fitted with radiotelegraph installation and searchlight, and – motor lifeboats fitted with searchlight only;

– liferafts, for which approved launching devices are required, capable of accommodating – persons; and

1 liferafts, for which approved launching devices are not required, capable of accommodating 20 persons;

8 lifebuoys;

45 lifejackets.

III. That the lifeboats and liferafts were equipped in accordance with the provisions of the Regulations annexed to the Convention.

VI. That the ship was provided with a line-throwing apparatus and portable radio apparatus for survival craft in accordance with the provisions of the Regulations.

V. That the inspection showed that the ship complied with the requirements of the said Convention as regards fire-extinguishing appliances and fire control plans and was provided with navigation lights and shapes, pilot ladder, and means of making sound signals and distress signals, in accordance with the provisions of the Regulations and the International Collision Regulations.

VI. That in all other respects the ship complied with the requirements of the Regulations so far as these requirements apply thereto. except as stated overleaf

**This certificate is issued under the authority of the** Panamanian **Government.**

**It will remain in force until** ..... **19** .....

**Issued at** ..... **the** ..... **day of** ..... **19** .....

LLOYD'S REGISTER OF SHIPPING

**The undersigned declares that he is duly authorised by the said Government to issue this Certificate.**

.....

Surveyor to Lloyd's Register of Shipping

71, Fenchurch Street, London, E.C.3.

NOTE:—It will be sufficient to indicate the year in which the keel was laid except for 1952 and 1965, in which cases the actual date should be given.

15m,8,66

# PART III

## SAFETY EQUIPMENT SURVEYS

### 1. General

Before a Safety Equipment Certificate can be issued the ship must be inspected by a Surveyor, who must satisfy himself that its life-saving appliances, fire appliances, navigation lights and shapes and means of making sound signals and distress signals are in good and efficient condition and comply with the requirements of the relevant Rules and Regulations.

An inspection cannot be carried out efficiently and expeditiously without the full co-operation of the Master who can save a considerable amount of time by making all necessary preparations before the Surveyor arrives on board. The Master is solely responsible for the continued efficiency and maintenance of all the items of Safety Equipment therefore, if the upkeep has been dealt with regularly and in a proper manner, the Surveyor's task in carrying out the examination is very much simplified and the survey can be dealt with smoothly and completed in one operation.

Owners should be encouraged to undertake the Safety Equipment Renewal Survey when the ship is in drydock or undergoing annual survey so that any repairs required can be readily dealt with. Certain tanker fleet Owners find it advantageous to renew all Certificates at yearly intervals at the time of the annual survey, thus ensuring that the ship can trade without interruption for the next 12 months. This obviates the necessity of arranging inspections at loading and discharging ports and the possibility and expense of the ship being detained with an invalid document.

### 2. Initial Survey

When the Society is requested to issue a Safety Equipment Certificate to a ship for the first time, an initial survey is to be conducted. This entails the preparation of a complete Record of Safety Equipment on the Rpt. SE1 in addition to the inspection and tests required for a Certificate Renewal Survey. The Form SE2 detailing the renewals and repairs effected, is also to be forwarded in all cases.

### 3. Renewal Surveys

As already stated, Safety Equipment Certificates are issued for a period not exceeding two years, without any intermediate survey being necessary, when they must ordinarily be renewed. The provisions for the extension of their validity have also been stated. The Renewal Survey is to be reported on Form SE2, giving a list of the renewals effected or repairs carried out, together with the dates of manufacture of all pyrotechnic distress signals and the last servicing date of inflatable liferafts. The Report 8 is not to be used for this purpose.

A complete Record of Safety Equipment is also to be prepared on the revised Rpt. SE1 at the next renewal survey held on all ships until a new form is prepared for each ship dealt with by the Society.

The scope of a Renewal Survey is as follows. No set pattern can be laid down as much depends upon the preparations made by the Master and the condition of the equipment. All items are to be examined and checked with the copy of the Rpt. SE1 which should be available on board to ensure that the equipment remains in good condition and readily available in the event of an emergency.

(a) Each fire pump to be operated separately to ensure that the two required powerful jets of water can be produced from different hydrants.

(b) All hoses to be ranged and examined under water pressure for leaks. Pay particular attention to the attachment of the hoses to the couplings.

(c) Examine the fire main, paying particular attention to the joints. Operate the isolating valves. Ensure that water is flowing at each hydrant and that hydrant valves are operating efficiently and the couplings are undamaged.

(d) Check the nozzles and international shore connections.

(e) Operate the emergency fire pump. Experience shows that independently driven fire pumps are not generally maintained and kept in good working order. Cases have arisen where the ship's personnel did not even realise that an emergency fire pump was provided.
Masters should be encouraged to use the emergency pump for providing water on deck for washing down purposes at least once every week and to ensure that the Chief Engineer carries out regular maintenance so that the pump can be immediately available for use whenever required.

(f) All portable fire extinguishers are to be discharged, examined for condition and recharged. Charges of non-portable extinguishers should be withdrawn to allow the extinguisher to be cleaned and examined. The piping system of a fixed fire smothering installation in the machinery space and/or cargo spaces is to be examined and blown through to ensure that it is free from obstruction and the operating gear inspected. If a smothering gas system is installed the contents of the $CO_2$ cylinders require to be checked by weighing or gauging and recharged if the loss of charge exceeds 10 per cent of the full charge.
It will be appreciated that this work is very time-consuming and would probably take one Surveyor several days to complete. The services of a reputable firm of specialists in the maintenance of fire appliances should be employed to deal with this part of the inspection. Such firms are established at all major ports and are able to provide facilities for the speedy and reliable overhaul of fire extinguishers and fire smothering installations including all the necessary repairs. The certificate of inspection presented on satisfactory completion of the survey should be attached to the Report Form SE2.

(g) The remote controls for stopping fans and machinery, and shutting off oil fuel suction pipes are to be tried under working conditions paying particular attention to the condition and efficiency of wires and sheaves serving quick-closing valves on oil fuel tanks. The closing arrangements of ventilators, funnel annular spaces, skylights, doorways and tunnel, where applicable, are also to be tested.

(h) Examine the firemen's outfits. Check that the breathing apparatus is complete and in good working order, air bottles fully charged, pumps or bellows operating efficiently and full instructions provided. It is also advisable to ensure that the Chief Officer and other crew members who are responsible for fire-fighting duties are fully

acquainted with the breathing apparatus and other fire appliances. The safety lamp and fireman's axe should be examined for condition, the lamp battery being renewed if the light lacks brilliance.

(i) The examination of lifeboats, davits and associated equipment can also be a lengthy process and again, it can be of great advantage to Owners to deal with this work at the time when drydocking or other surveys are being carried out and repairs or replacements can be readily effected with the minimum of delay and cost.

All lifeboats are to be turned out and lowered to the embarkation deck and as many as possible lowered to the water and released: motor lifeboats are to be given a running test afloat and their machinery installation examined.

All lifeboats are to be stripped of all equipment and portable air cases and examined externally and internally for condition. Wood lifeboats are to be specially examined for presence of dry rot, and in these surveys the Surveyor may employ the services of an experienced local boatbuilder or shipwright and is to obtain, and countersign, his report. Wood lifeboats not placed in the water should be hosed internally to test their watertightness. The Master's attention should be drawn to the importance of keeping a few inches of water in wood lifeboats or periodically hosing them during dry weather and placing them in the water at every opportunity.

In steel lifeboats all rust should be removed and the steelwork scraped, wire brushed and carefully examined for wastage, particularly the bottom shell and places where the boat has been in contact with wood or other materials or where chafing might cause wear and tear.

Aluminimum alloy lifeboats should also be carefully examined for condition, particularly behind the skates, their securing wire gripes and where metals other than aluminium have been in contact with the hull of the lifeboat. It is essential to ensure that paints applied to aluminium alloy lifeboats do not contain lead, only zinc chromate type primers and zinc oxide base paints should be used.

Fibreglass reinforced polyester plastic used in the construction of modern lifeboats will not corrode or rot, and therefore requires no maintenance. This material has, however, little resistance to wear by abrasion and in reinforced plastic boats it is important that gripes and lashings be prevented from chafing and the heavier gear inside the boat firmly secured to prevent scrubbing or working. Such lifeboats should be carefully examined and any serious fracturing of the fibreglass which may have been caused by a structural defect should be reported upon in detail. Permanent repairs to fibreglass, using raw fibreglass and resin materials, can only be satisfactorily effected by experienced persons and under ideal conditions of controlled temperature and humidity and no such repairs should be attempted without first removing the boat ashore to a suitable workshop. Patches coated with sealing compound and secured by self-tapping screws or through bolts can be used to carry out repairs of a temporary nature.

Portable air cases of all lifeboats are to be removed and carefully examined and if the Surveyor considers it necessary they should be tested for tightness by complete immersion in water. Where the buoyancy is in the form of permanently installed plastic foam built into the structure, no attempt should be made to remove the material. Following the internal examination of the lifeboat, the Surveyor should inspect the fittings and equipment permanently attached to the boat, i.e. lifting hooks, crutches, drain plugs, becketed lifeline, bilge keels, grablines, skates, provision and water tanks. The manual pump should be tested under working conditions and the rudder with tiller fitted in place. Mechanical disengaging and propelling gears are to be examined to ensure that they are in good working order.

(j) The lifeboat equipment is to be collected together and checked with the Rpt. SE1 (Sheet 6) and any deficiencies made good. Each item should be examined for condition, paying particular attention to articles of canvas and cordage which are subject to rot. The mast and sails (if required by the Regulations) are to be rigged. Compasses should be carefully examined and overhauled and tested by a competent person if required by the Surveyor. The first aid outfit container should be undamaged and free from rust with the lid seal intact. If considered necessary, the Surveyor should verify the condition of the provisions by sampling.

(k) When turning out the lifeboats the sheaves and other moving components of the davits and winches should be examined to ensure that they are well lubricated and moving freely. A common cause of trouble with davits and gear is the careless application of too much paint resulting in grease nipples and lubrication points becoming obstructed and pins, sheaves, etc., being rendered immovable.

It should be seen that wire falls are pliable and well greased, particular attention being given to parts that are normally out of sight and to the security of the end attachments. It is an advantage to turn cordage falls end for end before they show signs of wear in way of the blocks, thereby extending the life of the rope.

(l) When new gravity davits have been set up for the first time it is necessary to verify that the floating blocks will clear the horns in the davit heads with the ship listed to 15 degrees either way, the horns being usually made longer than required to enable fine adjustments to be made on board the ship with the lifeboat in place. If the horns are too long then the blocks might not clear at the required angle and if they are too short this might result in the blocks becoming unshipped at some point when being run out with the ship upright. Various methods can be used for checking the angle at which the blocks will clear the horns. That described below is considered sufficient for the purpose and capable of general application:—

Verify that the ship is upright and run out the davits to their full outboard position. By the use of a plumb line mark a vertical reference line in a convenient position on each davit arm.

Mark a second line on davit arm to cut this reference line at an angle of 15 degrees and in such a direction that when the davit arms have been moved through an angle of 15 degrees during the course of pulling in the davits, the second line marked will be vertical.

Pull in the davits until this second line marked on each davit arm is vertical and chock off the davits in this position by inserting wood chocks between the arms and

their outboard stops, or by other suitable means.
Lower the lifeboat a short distance. The blocks should clear the horns with the davit arms in this position indicating that they would also clear were the davits in the full outboard position with the ship listed 15 degrees adversely. It is obvious that it is unnecessary to make a similar check for a 15 degrees favourable list.

(m) Inflatable liferafts are to be inspected every 12 months at recognised Service Stations and the date of inspection reported. Liferafts of the rigid type are to be examined by the Surveyor at each Safety Equipment Survey for condition and the equipment checked with the list on the Rpt. SE1 (Sheet 7).

(n) All other items of equipment mentioned on the Rpt. SE1 are to be verified and examined for condition. The lifeboat portable radio equipment need not, however, be tested when the apparatus has been inspected at the same time as the main radio installation. Pyrotechnics are to be dealt with as follows:—

4. **Pyrotechnics**

Lifeboat smoke floats have an indefinite life providing the container remains in sound condition. All other distress signals, i.e. line-throwing rockets, parachute rockets, hand flares and lifebuoy markers such as Schermuly "Lifebuoy Marker" and Pains-Wessex "Manoverboard" and "Buoysmoke" signals are to be renewed three years from the date of manufacture unless their condition requires earlier renewal.

In cases where the signals are stamped with a date of expiry, they can be accepted as having the service life stated by the manufacturers even though this may extend beyond a period of three years.

The acceptance of valid pyrotechnic signals depends on their being properly packed and stowed and remaining in good conditions at all times. All pyrotechnics should, therefore, be carefully examined and, irrespective of age, be replaced at any time if found in an unsatisfactory condition.

5. **Damage Surveys**

The continuing validity of a Safety Equipment Certificate is dependent upon the equipment remaining in efficient condition and ready for immediate use. If any part of the equipment cannot be used due to damage or any other reason and the deficiencies cannot be made good without undue delay to the ship, then temporary arrangements are to be made of such a nature as to ensure that, for the intended voyage, the standard of safety is maintained. For example, cases may arise, particularly at remote ports abroad, where a lifeboat has been lost due to heavy weather and a replacement is unobtainable. It is essential that the loss of lifeboat capacity be made good before the ship proceeds to sea and temporary appliances in the form of inflatable liferafts of sufficient aggregate capacity to accommodate all persons on board are to be provided for a limited period, pending reinstatement of the lifeboat as soon as possible. The temporary provision of liferafts would also apply where a lifeboat cannot be launched due to defective davits. It will be appreciated that it is not possible to specify requirements to cover every eventuality and that each case will require to be considered on its merits according to circumstances. In general, however, where life-saving appliances or equipment required by the Collision Regulations are defective or deficient to a major extent, the ship should not leave port until either permanent repairs have been carried out or temporary measures have been taken to ensure that adequate equivalent provisions are made. All such cases should be referred to London Office giving full particulars of the deficiencies and the proposals for the provision of temporary arrangements, together with the time and place where permanent repairs or replacements are to be effected. Surveyors are reminded that any deficiencies in the fire-fighting appliances also affect the classification of the ship and it is necessary to forward a Rpt. 8 and issue an Interim Certificate of Class in addition to the normal Safety Equipment reporting procedure.

6. **Withdrawal of Certificate**

If, in any ship holding a Safety Equipment Certificate issued by the Society, defects are noted at any time in the fire appliances, life-saving appliances or other safety equipment items and these defects are, in the Surveyor's opinion of such a nature as to invalidate the Certificate, the defects must be made good to the Surveyor's satisfaction, otherwise the Certificate is liable to be withdrawn. London Office instructions are to be sought without delay in any case of this kind.

7. **Information and Observations**

Little is known in London Office about the facilities available at outports concerning the various aspects of the survey of Safety Equipment and the Surveyors are requested to assist in making good this deficiency. In order to compile a world-wide record in this connection, information is required as to what can be accomplished at each port and by whom, namely the supply of approved types of pyrotechnics, fire extinguishers, hoses, lanterns, signalling apparatus and items of equipment for lifeboats and liferafts, etc., the servicing of fire-fighting appliances, the inspection and replenishment of $CO_2$ and foam fire-fighting installations, the availability of new lifeboats and davits, the facilities available for carrying out major repairs and the approved servicing of inflatable liferafts. Such information would be invaluable in answering Owners' enquiries and in governing the period of validity of short-term certificates where outstanding items are involved. Any assistance the Surveyors can give to achieve the compilation of such data would be much appreciated

The Surveyors are also invited to forward their personal criticisms and observations as to any peculiar circumstances attached to Safety Equipment Surveys, but are asked to make such remarks in the form of a separate letter and not in the report. An indication as to the preparations made for the survey, the general condition in which the equipment was found, and observations as to the efficiency and disposition of the Master, Officers and crew in respect of life-saving and fire appliances is of valuable assistance to the International Conventions Department when each case is being considered.

8. **Conclusion**

The subject of Safety Equipment is wide and varied and could be enlarged upon to embrace other types of ships not catered for by the International Regulations such as cargo vessels of under 500 tons, yachts, tugs, trawlers, drilling rig tenders, etc., but these special cases receive individual attention in London Office and it is therefore unnecessary to specify their detailed requirements. It is considered that sufficient information has been set forth to cover most cases with which the Surveyors will ordinarily have to deal.

It is thought appropriate at this stage to finally stress that the utmost vigilance is required of the Surveyor when dealing

with matters concerning the safety of life at sea. Consideration should always be given to the consequences if a casualty occurred after leaving port and the Surveyor was called upon to give evidence at the court of inquiry. Before issuing *any* Certificate the Surveyor must, therefore, be satisfied that the safety measures are adequate and efficient. It must also be borne in mind that the Administration of any country has the authority to demand that a survey be held at any time in order to verify that the Safety Equipment is satisfactory. This form of supervision is becoming more frequent and where the equipment is found defective or deficient, legal action is taken by the Government concerned, heavy fines are imposed upon the Master and the ship is invariably detained until satisfactory measures have been taken. Furthermore, a detailed report is forwarded to I.M.C.O. for scrutiny by the Maritime Safety Committee and the findings are made known to all Member Governments. Some recent reports reveal cases of gross negligence, not only on the part of Masters for failing to maintain the Safety Equipment, but also as a result of dereliction of duty by the Surveyors. A study of the complaints reveals that insufficient attention is given to the condition of the lifeboats and davits, engines of motor lifeboats and the emergency fire pump and Surveyors should bear these facts in mind when undertaking future surveys.

The Author wishes to record his appreciation of the assistance he has received from members of the London Office Technical Staff and Outport Colleagues both at home and abroad in the preparation of this paper. The support of Miss M. Giles in typing the original draft, the Technical Illustrators, the Printing House Staff and other participants is also gratefully acknowledged.

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# SHIPS' ELECTRICAL INSTALLATIONS AND THEIR SURVEYS

Ir. W. de Jong

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# SHIPS' ELECTRICAL INSTALLATIONS AND THEIR SURVEYS

By Ir. W. de JONG

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## 1. INTRODUCTION

Some years ago the Electrical Engineer Surveyors of the Rotterdam and Amsterdam offices drafted guidance notes for electrical surveys.

The purpose of that exercise was primarily to assist the Engineer Surveyor when carrying out electrical surveys on new and existing ships and in factories.

The subject notes are additional to the Society's Rules and the Instructions to Surveyors, giving some general information concerning marine electrical systems and equipment and clarifying practical points which have not been mentioned in the Rules or Instructions.

As the contents of the above mentioned guidance notes might perhaps also be useful for Surveyors outside the district of Rotterdam and Amsterdam, the main purpose of this paper is to give an extract of those guidance notes, supplemented by some more general information about ships' installations and materials.

In particular, for the younger Surveyors, it might be worthwhile to mention that valuable information regarding electrical surveys and ships' electrical installations may be found in L.R. Staff Association Paper No. 3, session 1961-62 by Mr. W. Morris: "The Survey and Testing of Marine Electrical Equipment" and in the book "Marine Electrical Practice", written by Mr. G. O. Watson. Reference may also be made to publication 92 of the International Electrotechnical Commission: "Electrical Installations in Ships".

This publication has been issued in the following parts:—

Part 1. General Requirements, 1964.

Part 2. Graphical Symbols, 1965.

Part 3. Cables (construction, testing and installations), 1965.

Part 4. Switchgear, Electrical Protection, Distribution and Control gear, 1965.

Part 5. Transformers for Power and Lighting, Semi-conductor Rectifiers, Generators (with associated prime-movers) and Motors, Electric Propulsion and Tankers, 1965.

Part 6. Accessories, Lighting, Accumulator (Storage) Batteries, Heating and Cooking Appliances, Internal Communications, Lightning Conductors, 1965.

The I.E.C. publication might be used in addition to the Rules and can particularly be useful when specification cases have to be dealt with because it gives also recommendations for domestic and other non-essential equipment for ships.

## 2. GENERAL

The condition of a ship's electrical installation is, like that of all electrical installations, determined by the following factors:—

1. System Design.
2. Materials.
3. Installation, Commissioning and Testing.
4. Maintenance.

The first three items will have to be dealt with by the Surveyor during new building surveys; the result of the latter will be responsible for the necessary extent of the periodical surveys.

Generally, the first factor will not present serious troubles to the outdoor Surveyor responsible for the electrical first entry survey because the electrical circuit diagrams, indicating the system design, are approved by a competent Plan Approval office. Moreover, typical system design questions like the capacity of the generators; required protective devices; cable sizes; where to install fuses, switches, circuit breakers, measuring instruments, etc.; requirements for dangerous areas on tankers and similar ships; and many other questions of this kind are clearly dealt with in Chapter M of the Rules. An exception, however, may be made in this respect for the subject of short-circuit current calculations and discrimination of protection devices. These system design points quite often cause some problems. Item 2 of the above list, however, represents the most difficult point for the Surveyor. It is not an easy task for an outdoor Surveyor, carrying out new building surveys, even if he is an electrical engineer by profession, to ensure that the electrical materials are of sufficient quality for shipboard use.

It will be well known to all Surveyors that shipboard conditions are generally very unfavourable for electrical equipment. The climate classification of the British Standard Code of Practice: CP 1014:1963, dealing with protection of electrical power equipment against climatic conditions, includes the marine conditions under the heading "extreme severity".

Some of these arduous conditions are:—

(i) High and low ambient temperatures.

(ii) Continuous operation.

(iii) Little or no specialist voyage maintenance.

(iv) Limited specialist service and repair facilities in most ports, particularly ouside the country or continent where the equipment was manufactured.

(v) Relatively large and often rapid supply voltage and frequency variations.

(vi) Vibrations and shock.

(vii) Unfavourable electrical conditions, e.g. oil mist, salt air, moisture, dust, etc.

(viii) Rolling and pitching.

(ix) Very adverse conditions during the building period.

The above conditions are much more severe than those which are normally encountered in industrial installations. Yet there is a tendency to use more and more standard land equipment in ships' installations.

And although during the last 10 or 20 years the availability of new materials, particularly insulating materials, and manufacturing techniques generally, have improved the quality of electrical equipment, it is the Author's opinion that in the near future the subject of selecting electrical materials for ship installations will need more and more attention from the Surveyor.

Chapter M of the Rules deals with cables and to some extent with electrical machines, transformers and switchgear specific constructional and testing requirements in which the ship's environmental conditions have been taken into account. Generally, reference is made to international or national standards—which are almost all drafted for industrial equipment. Consequently a vast field is left to the initiative of the designer of ship's electrical installations—and to that of the Surveyor.

This is rather a logical situation as it would be impracticable and perhaps impossible to specify constructional requirements for every piece of marine electrical equipment, particularly when the different design and manufacturing practices of the various parts of the world in which ships are built to our class are taken into consideration.

Nevertheless, this subject quite often presents problems to the Surveyor.

The above mentioned arduous operating conditions make it necessary that when examining electrical materials intended for marine installations, the following points deserve particular attention:—

(i) Materials should be non-hygroscopic. This means that coils from relays, contactors, etc., must be impregnated, encapsulated or insulated with non-hygroscopic materials. In this respect attention must also be given to busbar isolators, insulated baseplates or barriers, terminals, etc. Sometimes insulating materials like resarm (pressed laminated wood) can be made sufficiently non-hygroscopic by means of a suitable varnish.

(ii) Materials should be resistant to vibration and shocks. This is a difficult subject. The following points may be important:—

(a) All connections should be provided with suitable means for locking and should be adequately tightened. It is the Author's opinion that a large percentage of faults in ships' electrical systems, ranging from innocent failures of equipment up to serious black-outs or fires, is caused by loose connections. Possibly the best connections are obtained with suitable cable shoes fixed by screws or bolts and nuts, with lock washers. Satisfactory results, at least for light cabling or wiring, can also be obtained with "klippon" and similar patent type terminals, provided the systems have locking facilities. Systems using mechanical clamps for the connection of conductors, as often found on contactors and similar equipment, are not favoured by the Author because, due to "setting" of the stranded conductor cores under the clamp, the pressure decreases and, if such connections are not regularly checked, this could result in bad connections. Care should be taken before accepting special patent connection methods like "Faston slide-on" connections, wire wrap systems, etc. Most of these connection methods are not very suitable for marine equipment. It is often stated that such connections give satisfactory service results in motor cars, washing machines, etc. However, the number of working hours of such machines are negligible compared with those to be expected for ships' equipment. Moreover, although the vibration conditions could be similar, the remaining ambient conditions are not quite so severe.

(b) Removable racks and chassis, like withdrawal motor starter units, should preferably be positively located by screw type fastenings and not by latches only.

(c) Plug-in components such as relays, plugs, etc., should be clamped in position and not just a friction fit.

(d) Controls which are liable to move under shock and vibration conditions should be locked.

(e) Internal wiring should have stranded conductors. All leads should be properly secured. This is particularly important where short leads go from the cable form to soldered connections.

(f) Components of more than 50 grams weight and lighter components with fragile leads, should be adequately secured to the chassis or printed circuit board and not just held in position by their connecting leads.

(iii) Materials should be able to withstand the ambient temperatures to be expected on board ships. Paragraph M 106 mentions 45°C as the cooling air temperature for which electrical equipment should be designed. This is, however, not the maximum temperature which will be found on board ships. The actual local temperatures in machinery spaces can be substantially higher, even up to 65°C. However, for electrical power equipment like machines, transformers and cables, this 45°C Rule gives satisfactory results, mainly because during limited periods such equipment can stand those higher temperatures and because they are not always running with full load. However, for electronic equipment, relays, capacitors, internal wiring of panels, etc., such high temperatures could be dangerous.

Moreover, an extra temperature rise can be expected when equipment is located in panels or cubicles due to dissipation of the heat of its own components and/or due to heat radiation from hot machinery parts or from the sun.

Besides the well known hot places such as near boilers, heated fuel oil tanks, etc., special attention is to be given as far as temperatures are concerned to auxiliary enginerooms, enginerooms of small motor vessels (coasters) using heavy oil and particularly to enginerooms of

motorships where the combustion air for the engine is supplied directly from the open air and not via the engineroom as such a system reduces the air circulation in the engineroom considerably.

In view of the above in the Author's opinion all equipment for ships, at least that for installations in machinery and similar spaces, should be able to withstand 65°C; power equipment for short periods and electronic and similar equipment continuously.

(iv) Equipment should be able to withstand a high humidity, salt air, oil mist, etc.

This means that the following points should be observed:—

(a) Equipment should be protected against corrosion. Special attention should be paid in this respect to laminated iron cores of transformers and relays, springs of contactors, brushholders, etc., sheet steel panels and starter or distribution panels, cable clipping materials, bolts, nuts, screws, etc. In view of corrosion the thickness of the sheet steel used for panels, etc., should generally not be less than 1·5 mm as with thinner steel it will be extremely difficult to protect it sufficiently against corrosion during the course of the 20 years during which it is expected to operate.

(b) When different metals are used care should be taken to avoid electrolytic action and the subsequent destruction of one of the materials. This is particularly important for equipment mounted on decks. The earlier mentioned Code of Practice CP 1014:1963 deals extensively with the matter.

(c) Materials should be resistant to oil and oil vapour, unless used in suitably enclosed compartments or cubicles.

This may be particularly important for insulation of cables and wiring, sealing materials used in cable glands, insulating varnishes used in machines, etc.

(d) Insulating materials should have sufficient ability to withstand tracking.

Tracking is the breakdown of a solid insulating material due to leakage currents over its surface between the live parts.

These leakage currents can arise because a layer of moisture and/or dirt gives a conductive path. If a material has insufficient anti-tracking properties these leakage currents cause carbonization of the insulation surface and finally this results in a complete breakdown.

The tracking characteristics of an insulating material may be determined by carrying out tracking tests, e.g. according to I.E.C. publ. 112.

I.E.C. 112 gives a method for determining the comparative tracking index of solid insulating materials under moist conditions. This method may briefly be described as follows: Two electrodes are placed at a specified distance on a flat surface of a sample of the subject insulating material. A voltage is applied between the two electrodes and drops of a solution of ammonium chloride in distilled water having a concentration of 0·1 per cent are allowed to fall on the test surface midway between the electrodes. The comparative tracking index is defined as the voltage between the electrodes at which no breakdown over the surface occurs when 50 drops are allowed to fall on the test specimen.

It is the Author's opinion that for marine electrical equipment the tracking index of insulating materials, determined in accordance with I.E.C. 112, should be at least 175 volts.

Anti-tracking characteristics of a material can be improved by the application of an anti-tracking varnish. The risk of a breakdown can also considerably be reduced by good maintenance.

However, on a modern ship there will not be much opportunity for regular cleaning of insulating surfaces. Main switchboards, group starter panels, distribution and section boards, etc., are continuously in service, often even when in drydock. Good insulation of main items, like busbar insulation, insulation of main circuit-breakers and contactors, etc., should therefore not be dependent on maintenance.

It is, therefore, increasingly important to use good materials and, on the other hand, to design panels, switchboards, etc., so that the accumulation of dirt and moisture is prevented as much as possible.

In order to get an idea how in practice the tracking phenomena affects electrical insulation, a switchgear manufacturer has carried out tests under actual conditions. As the results of these tests might be interesting, a summary of the tests and the results follow here. The tests were carried out during approximately four years under various environmental conditions and with various materials.

The materials included: Bakelites (phenol-formaldehyde synthetic resins with various fillers such as paper, asbestos, linen or wood), melamine, polyesterglass, polyamide ureum and polyethylene.

The environmental conditions included: Sea air ambient, dry but dirty air ambient, humid air ambient.

The results indicated that:—

(*a*) The differences in the characteristics of the various materials are not very great. However, bakelites clearly are less anti-tracking than the other insulants mentioned above.

(*b*) For bakelites the length of the creepage distance hardly affects the anti-tracking properties. If a breakdown occurs at a distance of 4 mm, it will also occur when the creepage distance is enlarged to 8 or 16 mm.

For the better materials a larger creepage distance reduces the risk of having a breakdown.

(*c*) Horizontal surfaces are much more dangerous than vertical surfaces.

(*d*) During the tests breakdown only occurred when the test specimen was in a humid environment, dry dirt alone was insufficient to introduce tracking.

(*e*) If the equipment is continuously alive the risk of breakdowns from tracking is considerably less than when the voltage is switched on intermittently.

Figs. 1 and 2 show pieces of insulating materials which failed due to tracking.

The sample shown in Fig. 1 is a piece of bakelite used under the terminals of a hot water boiler. The creepage distance was 10 mm and the voltage 220 volts a.c.

The sample in Fig. 2 is an isolator made from compressed asbestosphenol. This isolator was for some years used on a transportable conveyor in the open air and the applied voltage was 300 volts a.c. The creepage distance was in excess of 100 mm.

(v) Materials used in connection with electrical equipment should be flame-retardant or incombustible. The reasons for this are self-evident. I.E.C. 92, part 1, contains test-methods to determine the incombustible or flame-retardant characteristic of materials.

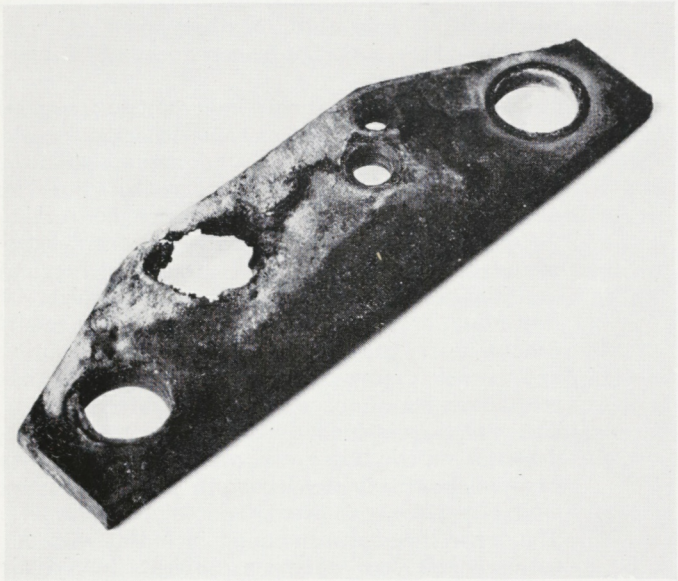


FIG. 1

A failure due to tracking.

(vi) Equipment should be suitably enclosed. This point also is self-evident. For machinery spaces dripproof enclosures will normally be sufficient, although totally-enclosed equipment is far better protected against the adverse effects of the environment.

It must be ensured that dripproof characteristics are maintained when pitching and rolling or when having a permanent list.

I.E.C. 92, part 1, also contains test methods for dripproof, splash-proof, watertight, deck watertight and submersible enclosures.

The above considerations deal with the environmental conditions to which electrical equipment is exposed.

Marine control engineering equipment has to operate in the same unfavourable ambient. In view of this our Society issued an "Environmental Test Specification for Control Engineering Equipment" and equipment so tested may be included in our "List of Type Tested Control Engineering Equipment".

It might be worthwhile to consider the issuing of a similar test specification for marine electrical power equipment such as contactors, switches, circuit-breakers, terminals, etc. Such

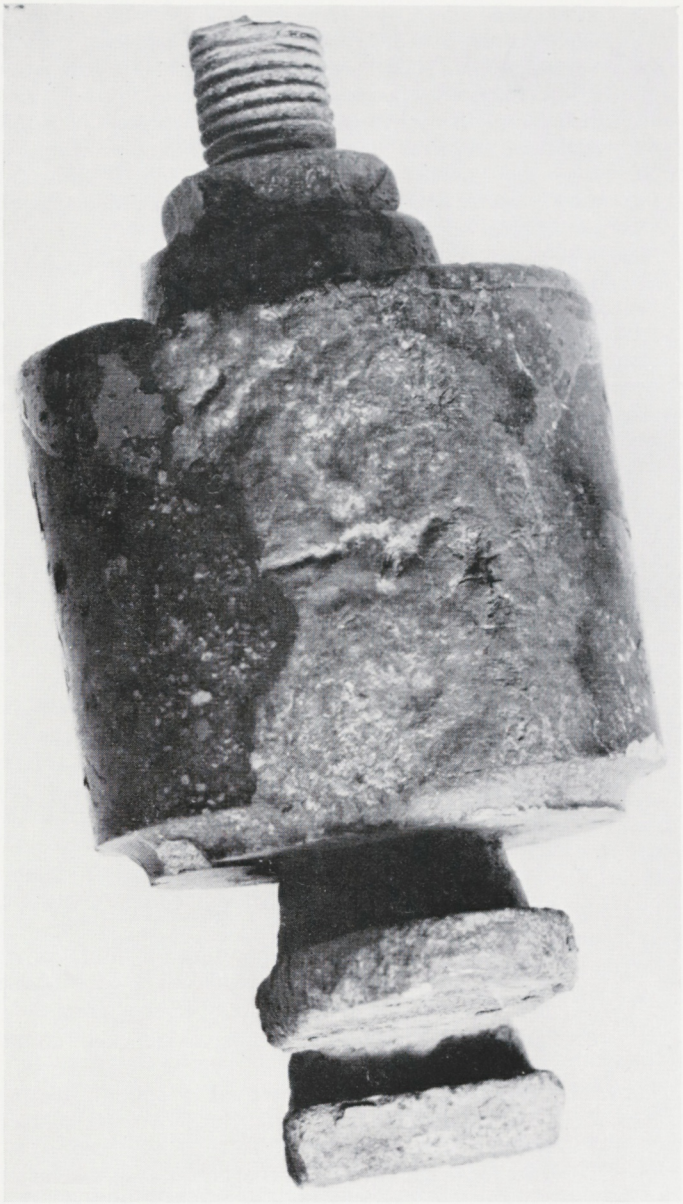


FIG. 2

A failure due to tracking.

a test specification could possibly also include a salt mist test and a tracking test for the insulating materials. The procedure could be that to ensure an entry in a list of approved equipment the manufacturer must show evidence to prove that this equipment complies with a suitable international or national standard and in addition tests would have to be carried out in accordance with a marine environmental test specification.

The third item of the list mentioned at the beginning of this chapter refers to installation, commissioning and testing. This concerns installation methods, workmanship and testing practices.

As was explained for Item 2 Materials, these subjects cannot be fully specified in Rules and Regulations and consequently here also a vast field is left to the Surveyor's own initiative.

These subjects will be dealt with in the following sections.

In view of the above it must be realised that it is not easy to ensure that the standard and quality of electrical installations are reasonably equal, independent of district or yard, as so much is dependent on opinions and interpretations and on what materials are available to the builder.

The last item of this Chapter refers to maintenance and, in fact, this subject falls outside the scope of this paper. One point should, however, be remembered during the new building survey, namely that it must be possible to carry out maintenance or repairs. Accessibility is therefore a very important point.

## 3. ELECTRICAL MACHINES

### (a) Insulation of electrical machines

The life expectancy of electrical machines is mainly determined by the condition of the insulation of the windings. Apart from dirt, moisture and other external causes the condition of the insulation is governed by the ageing of the insulating materials.

This ageing depends, amongst other things, on the working temperature. Therefore the insulating materials have been divided into classes and each class has a maximum allowable working temperature. Each machine must be so designed that the winding temperature under working conditions does not exceed the maximum allowable temperature of the insulating materials used.

The maximum ambient temperature, i.e. 45°C for unrestricted services, must be taken into consideration. On this basis the Rules give the allowable temperature rises of the windings of electrical machines, depending on the class of insulating material and the type of machine.

The classes of insulation have been given in the Instructions to Surveyors. Insulation class A is no longer used for new machines. Almost all machines now built have class E or B insulation, whilst the use of class F becomes increasingly popular, particularly for a.c. generators.

Machine insulating materials can be divided into two groups: Wire enamels to insulate individual round or rectangular conductors and insulating films and fibres for use as slotliners or to insulate individual conductors or a group of enamelled conductors. Many new insulating materials have been introduced during the last few years, wire enamels as well as insulating films or fibres.

Not long ago enamelled wires were used only in class E marine electrical machines; for class B the wires were insulated by glass fibre, asbestos-glass fibre or similar. The class E enamelled wires were mostly insulated with an enamel on base of polyvinylformal ("formex" and similar wires) or on base of polyvinylformal phenolic ("forvar" and similar wires). With these wires, although having limited thermal capacity, excellent results have been obtained. One of the reasons for this is that polyvinylformal enamels adhere extremely well to a copper conductor and give a mechanically strong enamel, able to withstand rough handling during the machine manufacturing process and machine vibrations in service. Enamelled wires or class B have been in use for some years. The enamels of these wires are mostly based on terephtalic acids or on polyesterimide. The thermal capacity is better than that of the above mentioned class E wires and the inclusion in class B is well justified. However, an important disadvantage of class B wires, particularly when enamelled with polyester varnishes based on terephtalic acids, is their weakness to withstand mechnical damages. Faults are easily introduced during manufacturing. In this respect it must be remembered that thermal capacity is not the only important feature when considering wire enamels. Mechanical strength, good adherence to the conductor, thickness of the enamelling, ability to withstand the effects of impregnating varnishes, solvents, moisture, oil, etc., are just as important. Many machine failures have occurred in recent years due to poor mechanical characteristics of class B insulated wires.

Wire enamels based on polyesterimide enamels are generally mechanically stronger than those based on terephtalic acids, although not as strong as the normal class E enamels. Some enamelled wires with enamel based on polyesterimide are suitable for class F.

Many failures in machines, particularly when wound with enamelled wires, commence as a short-circuit between turns of a winding. This results in strong overheating of the subject winding and will finally cause the machine to burn out. The high-voltage test and megger test on a completed machine will not reveal weak insulation between turns of a winding. Most manufacturers therefore introduce during their manufacturing process a special winding test to check the interturn insulation. Such a winding test can be carried out in several ways. One of the possible methods is to apply an induced high voltage test, similarly as the test mentioned in paragraph M 808 for the windings of a transformer. Another possibility is to use special surge test equipment with which a high peak voltage is applied between the turns of a winding and which method directly shows whether the winding is good or not.

Summarizing it may be said that the mechanical characteristics of enamelled wires are very important and it may be recommended to check regularly the winding departments of machine manufacturers to make sure that the right wires are used and that sufficient care is taken when the windings are made.

Also, strong wire will finally break down when roughly handled or laid in slots of which the edges are sharp and not sufficiently protected by the slot lining. Besides the well known insulating films or fibres such as glass fibre, micanite, cellulose triacetate, etc., for a number of years films and fibres of polyethylene terephtalic (polyester) have become very popular. This concerns Melinex, Mylar and Hostophan films and terylene fibres or similar polyester materials with other trade names.

These materials were originally introduced as class E materials and were mainly used to replace cellulose triacetate or similar materials or laminates. However, these polyester films have generally been recognised as class B materials and are often used to replace mica or micalaminates. The mechanical characteristics of polyester films are excellent and until now the results obtained with this material are very good. Also laminated films are used one layer of which is polyester. The other layer can be paper, cellulose triacetate, micasplitting, etc. It is often difficult to determine the insulation class of such a polyester laminate because the various layers used in one laminate may have different classes of insulation. Although in this respect each case must be considered on its own merits, it will generally be acceptable to take the insulation class of the "thickest" layer as the insulation class of the laminate.

Glass fibre, mica and micanite films, and similar materials are still very often used and these materials are also suitable for class F machines.

A new material becoming increasingly popular is Nomex, an insulating film based on aromatic polyamide, mechanically very strong and suitable for use up to class F.

Apart from the choice of the insulation materials, the impregnating varnish and the manner in which the impregnating process is carried out is of considerable importance for a machine.

The thermal capacity of the impregnating varnish should match the class of insulation of the used insulating materials and should not be chemically aggressive towards the enamelled wires or the other insulating materials. Before the impregnating varnish is applied to the machines, the machine must be thoroughly dried. This can be done by heating or by applying a vacuum. After application of the varnish the machine must be dried. The drying time and temperature depends on the type of varnish and the size of the machine. The purpose of impregnating is to protect all hygroscopic materials and in general to fill all holes between insulating films, wires, etc.

Unfortunately, normal impregnating varnish contains a solvent, usually approximately 50 per cent. This means that after one impregnation cycle all holes are only 50 per cent filled. This is one of the reasons that mostly the impregnation process is at least carried out twice. For machines of open or drip-proof construction it should be required to impregnate at least two times; for totally enclosed machines it is of less importance. Sometimes quick drying varnishes are used, particularly in repair shops. This is not very attractive: firstly, because the solvent content may be very high, thus leaving less varnish in the machine, and secondly, because a quick drying varnish often becomes very hard. A hard impregnating varnish does generally not resist temperature changes and will crack, so decreasing the machine insulation.

Many manufacturers apply a final layer of resin on the insulation after impregnating.

This resin is an extra precaution to decrease the effects of dirt and moisture and to provide additional protection against tracking.

As regards impregnation of machines, it may be added that when using modern insulating materials, such as polyester films, the attachment and penetration of the varnish is not very great and its function is mainly the filling of openings between the winding wires and the insulation.

### (b) Insulation resistance of electrical machines

The condition of the insulation of an electrical machine can, more or less, be determined by measuring the insulation resistance, e.g. to earth or between the windings. Checking the insulation resistance does not, however, give an absolute picture of the condition of the insulation. For instance, when the machine is very dry the insulation resistance can be very high although the insulation materials may be worn out. On the other hand, a good machine which has been in a humid place during a long time, will show a very low insulation resistance.

In the first case the machine has actually to be rewound, whilst in the latter it will suffice to dry the machine. These two extremes show that measuring the insulation resistance does not necessarily give a correct picture of the insulation of a machine.

The insulation resistance should be measured before placing the machine in service. For new machines the insulation resistance should be at least 1 megohm. For machines in service (at periodical surveys) 1000 ohm per volt is often considered as a reasonably acceptable value; 0·1 megohm is the minimum allowed by the Rules. For 440-volts machines an insulation value of 0·1 megohm may, however, be considered as dangerously low.

If the insulation resistance is lower the necessary arrangements should be made, such as drying, re-impregnating or, when necessary, rewinding. Where possible the insulation resistance should not only be measured between the combined winding and earth, but also between the windings, i.e. between the phases of an a.c. machine. This is particularly important when the machine is suspect due to signs of external damage or the ingress of water or when the value to earth is not far above the acceptable limit. It must be remembered that the highest voltages in service will be found between the windings. It is also important to earth temperature sensors inserted between windings when the insulation resistance is measured. If this is not done a possible fault between the windings and those sensors would not be detected. Care must be taken that a.c. generators of the self-regulating type are not subjected to a megger test before it is ensured that diodes or other semi-conductor devices are disconnected or short-circuited. In this respect the maker's instructions should be followed. The insulation resistance is measured with so-called "meggers"; usually at a voltage of 500 volts, sometimes at 1000 volts; when using some of the new insulation measuring devices which are fed by small batteries the voltage should be checked carefully as a certain number of these devices give a much lower voltage.

### (c) Ventilation and enclosures

Machines must be installed in such a way that the ventilation is efficient and corresponding to the machine design. Sometimes machines are partly installed below the engine-room floor or 'tween deck floors. This is not a good practice, particularly when drip-proof machines are used. Firstly, because it is often difficult to arrange that the ventilation openings of the machines are not blocked by floor plating, pipes or machinery parts and, secondly, because the ventilation air allowed to enter the machine will be extra dirty and oily.

Generators are mostly fitted on a common baseplae together with the driving engine. It must be ensured that the ventilation of the generator is not hindered by the baseplate construction or that due to the baseplate construction the hot air leaving the machine is not again led to the ventilation inlets.

With force-ventilated machines it will often be difficult to carry out the heat run test at the factory under the same ventilating condition as will be found on board. The real operating conditions should be simulated as much as possible or otherwise adequate calculations should be shown to prove that the ventilation will be satisfactory. It will generally be wise to provide alarms on the ventilation of forced-ventilated machines because, in most cases, failure of the ventilating fan motor will cause a very quick rise in machine temperature. With water-cooled machines it is, of course, a well known fact that extreme care must be taken to prevent any cooling water leaks from reaching the machine windings. Nevertheless, this happens now and then, mostly with disastrous results for the machine.

Machines should preferably have openings to drain off water formed by condensation. This is not necessary for small totally enclosed machines because the amount of free air present in such machines is insufficient to cause a significant condensation. The drain openings should be continuously

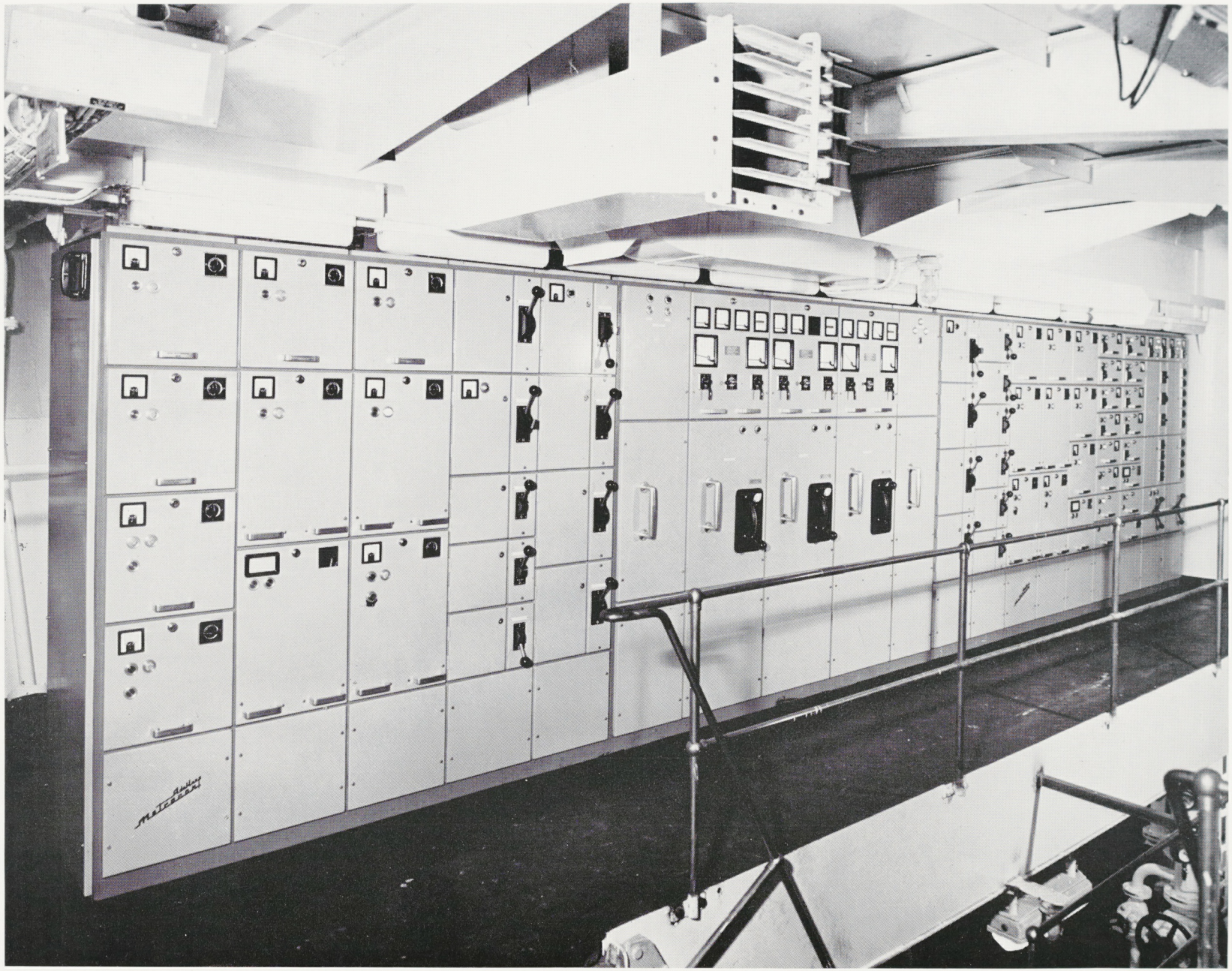


FIG. 3

A modern a.c. switchboard.

open, except for machines on open deck which should have plugs.

It sometimes happens that motors designed for vertical mounting are used horizontally or reverse. With this practice it must be ensured that the bearings are not overloaded, that the machine enclosure is suitable for the actual mounting position (most vertical drip-proof machines will not be drip-proof when used horizontally) and that the condensation drain opening is at a suitable place.

## 4. MAIN SWITCHBOARDS AND DISTRIBUTION SWITCHBOARDS

The purpose of a main switchboard is:—

(i) Control and protection of the generator circuits.

(ii) Distribution of the electrical energy by means of outgoing circuits, provided with switchgear and protective devices.

The main switchboard is the "heart" of the electrical power installation of a ship.

Besides a main switchboard, on most ships there will be an emergency switchboard, section boards, distribution boards and sometimes centralised motor starter boards.

Figure 3 shows a photograph of a modern a.c. switchboard manufactured by Messrs. A. de Hoop N.V., of Rotterdam.

The following notes may be useful with respect to the construction of main and other switchboards.

A major requirement for all switchboards is that their short-circuit current capacity is sufficient for their particular application. The available short-circuit currents are dependent on the generator characteristics, transformer characteristics, current feed-back from running motors and the impedance of cables. A separate section of this paper gives some notes about short-circuit current calculations and general protection problems.

Circuit-breakers and fuses are selected on rated circuit current and short-circuit capacity. Our List of Type Tested Circuit-breakers is of great help for switchboard designers as it gives the most essential details of a great many of the circuit-breakers available on the market.

However, it is not always understood by manufacturers that this list is not a list of approved equipment. As it is clearly said in the foreword, it provides details on breaking and making capacity and temperature rise but as regards suitability for marine conditions the circuit-breaker must be examined for the particular application proposed to ensure that it is suitable. Points to watch are construction of coils; type and fixing of auxiliary wiring; general robustness of breaker constructions; provisions to connect cables or busbars, particularly with respect to required locking arrangements; type of insulating materials which should be non-hygroscopic and anti-tracking.

Main circuit-breakers such as those for generator circuits and major outgoing supplies, should preferably be provided with means of isolation fitted between breaker and main busbars or should be withdrawable.

It is also a very good practice to provide links or isolating switches between generator sections and outgoing group sections. With this arrangement it is possible to supply energy to essential consumers, also when one complete busbar section is inoperative due to fire, short-circuit or other accidents. The usual arrangement is to have the generator panels in the centre of the main switchboard and outgoing circuits on both sides. Main and stand-by supplies are then supplied from different switchboard sections.

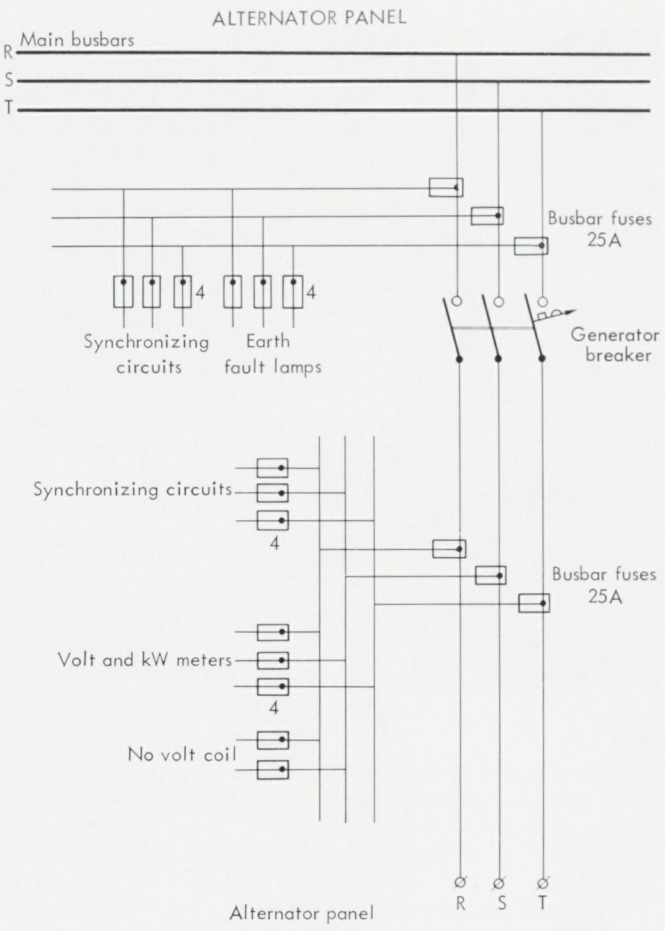



FIG. 4

Protection of switchboard secondary wiring.

Secondary wiring in switchboards for meters, protection circuits, no-volt coil circuits, synchronizing circuits, etc., are normally protected by fuses. It is a good practice to protect the supply wiring for these systems by main fuses, mounted directly on the busbars.

Fuses for the individual secondary circuits are then located at a suitable place somewhere else in the switchboard. Such an arrangement is shown in Fig. 4.

It is important to provide separate protection for breaker control, protection and measuring circuits to avoid one faulty piece of equipment preventing other circuits from operating.

Main circuit-breakers are often motor operated, either direct or via a spring, where the spring is wound by the motor. Besides such mechanical closing, manual operation will also be possible. In such a case it is essential to protect the closing motor circuit separately from the no-volt coil circuit to avoid a failure in the motor closing circuit preventing hand operation because the no-volt coil circuit cannot be energized. The same philosophy may be applied regarding the protection of manual and automatic synchronizing devices

There are still main switchboards built with manual synchronizing, using only synchronoscopes and synchronizing lamps. With this arrangement good synchronizing is purely dependent on the skill of the operator.

The effects of malsynchronizing can be very serious:—

(a) Damage to switchboards because generally circuit-breakers are not designed and capable to disconnect generators connected to the switchboards when the voltage is about 180° out of phase, causing currents in the order of full short-circuit currents to be interrupted at voltages higher than the rated voltage.

(b) Mechanical damage to the generator sets due to the high torques which may arise.

(c) Damage to the generators due to the high currents.

It is doubtful, also taking into account the standard of crews found on many ships, particularly smaller ships like coasters and which have now also a.c. installations, whether it is still justified to accept systems using manual synchronizing only.

The alternatives are to use automatic synchronizing equipment or synchronizing chokes. Automatic synchronizing equipment compares automatically frequency, phase difference and sometimes the voltage of the generator with that of the main busbars. When these are correct the breaker gets an automatic order to close, i.e. when motor- or spring-operated breakers are used, or the breaker is given free to be closed manually. Not all automatic synchronizers are suitable for use in conjunction with manual operated breakers because some maintain a closing order during a certain period at the end of which the machines could be no longer in synchronism. Should the breaker be closed at that moment damage could occur.

The closing time of a breaker, i.e. the time elapsing between a closing order, e.g. pressing a button, and the actual closing of the main contacts, is important for synchronizing. Circuit-breakers with a long closing time are not very suitable for use as generator breakers. When synchronizing generators, automatically or manually, the goal is that the main contacts are closed at the moment of synchronism.

When the closing time is 150 milliseconds this means that the closing order must be given 150 milliseconds before synchronism is reached. When the frequency difference between the system is about zero this is no problem because synchronism, once obtained, will stay on.

However, a frequency difference of about zero is not convenient because it may take a very long time to reach synchronism. Therefore the frequency difference at which synchronization is carried out is often about 0·5 c.p.s. At this frequency difference the pointer of a synchronoscope makes one revolution in two seconds. When the frequency difference is 0·5 c.p.s. and the closing time is 150 milliseconds the breaker closing order should be given when the phase angle between the generator and the busbars is 27 electrical degrees; i.e. when the synchronoscope pointer indicates approximately ten minutes before 12 o'clock.

A good automatic synchronizing apparatus takes this into account and has adjusting possibilities for the synchronizing frequency difference and the pre-order time (this time should be equal to the breaker closing time).

The danger with systems employing slow closing breakers is that when conditions change after the closing order is given, the possibility exists that the breaker main contacts might close when the machines are not in synchronism. If, for instance, 50 milliseconds after a closing order has been given a big motor is started the main busbar frequency will suddenly drop. This could have as a result that when, 100 milliseconds later (supposing the closing time is 150 milliseconds), the main contacts are closed the machines could be out of synchronism.

This problem can be overcome by using contactors (suitably protected by fuses) parallel to such slow operating breakers. With this system an order is given by the automatic synchronizer to close the contactor. When the contactor is closed (within 20 or 30 milliseconds) the main breaker is closed via auxiliary contacts and finally the contactor is opened again. When a system is employed using synchronizing chokes care should be taken to ensure that the synchronizing choke is suitably protected. The thermal capacity of such synchronizing chokes is often very limited and consequently they can easily burn out when for some reason repeated attempts for synchronizing are made. It is, therefore, advisable to provide the synchronizing coils not only with fuse short-circuit protection but also with thermal relays preventing repeated synchronizing.

Outgoing circuits from main and emergency switchboards must be provided with fuses and switches or circuit-breakers. It is strongly advised to place the fuses between the busbars and the switches to avoid a faulty switch from causing a main busbar fault.

All connections between main busbars and outgoing fuses or breakers should be able to withstand the mechanical and thermal effects of full short-circuits, during the time needed for the generator breakers to interrupt the fault. Switches should be able to be switched in on short-circuits, i.e. their making capacity should be sufficient for the available fault current level. If a switch is located behind a fuse it is sufficient that its making capacity is equal to the current let-through by the fuse, i.e. the fuse cut-off current.

In some countries motor group starter boards are popular, consisting of fixed or withdrawable motor starter units. Where such systems are directly connected to the main busbars of the main switchboard care must be taken to ensure that the supply connections, including the plug-in units have adequate short-circuit capacity. When withdrawable units are used this is very difficult to realise. To reduce the available short-circuit current on such panels often the withdrawable starter units are supplied via back-up fuses mounted near the busbars.

One set of back-up fuses supplies in that case one or two vertical rows of starter units forming a section of a switchboard. It must be ensured that main and stand-by equipment is not supplied via one set of back-up fuses. Of course, similarly, main and stand-by equipment should not be supplied from the same section or distribution board. Fig. 5 shows an arrangement where withdrawable starter units are supplied from the main busbars via back-up fuses. Fig. 6 shows a photograph of a switchboard with withdrawable starter units manufactured by Messrs. Croon & Co., of Rotterdam.

Outgoing circuits from distribution boards need not be fitted with switches, fuses only are sufficient, although for major distribution boards supplying sub-distribution boards it is also advisable to install switches.

All electrical connections, switchgear contacts and further equipment in switchboards must be accessible.

It should not be necessary to dismantle other switchboard parts before maintenance or repairs can be carried out to equipment in switchboards.

Ample room for inspection of switchgear must be provided.

Boards which are not accessible at the rear must be so constructed that all parts and connections are accessible from the front. This is generally very difficult to realise and, in view of

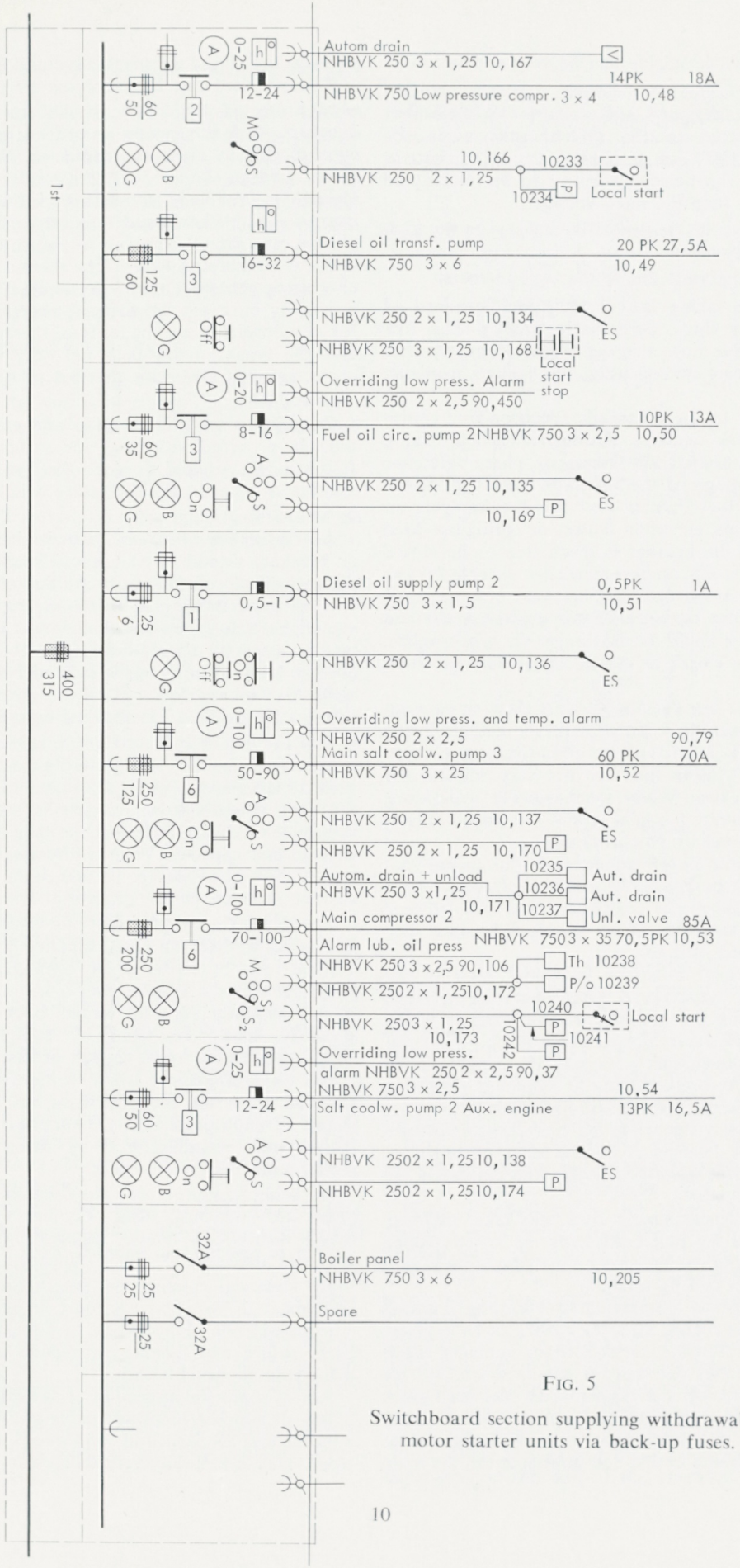



FIG. 5

Switchboard section supplying withdrawable motor starter units via back-up fuses.

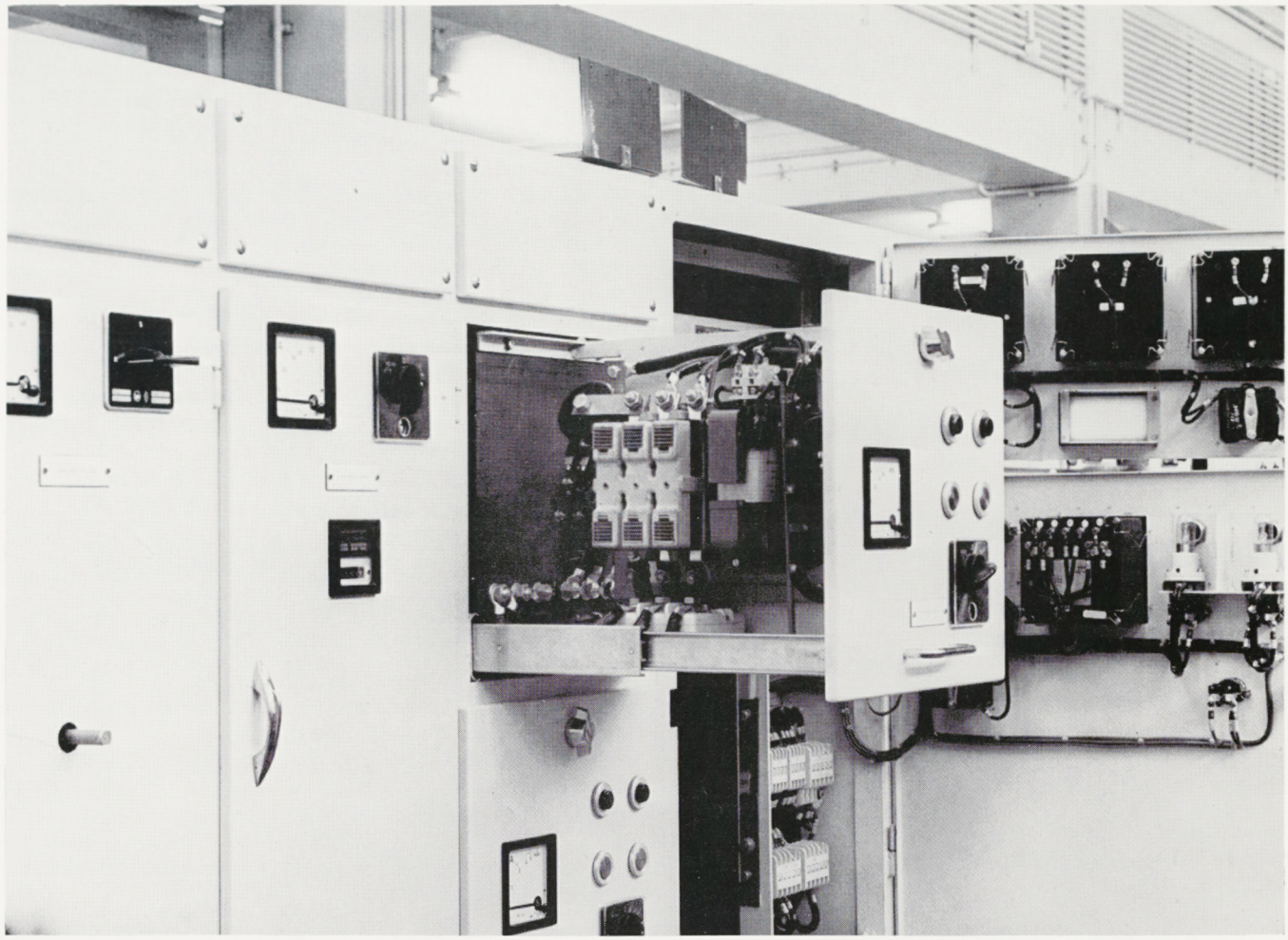


FIG. 6

Switchboard with withdrawable motor starter unit.

this, it is strongly recommended, particularly for main switchboards, that boards are accessible from both sides. Front plating should be easily removable and should preferably be constructed with hinged doors. When switches are fitted in front plating it must be ensured that it is possible to remove the plating without the need to disconnect circuits. It is essential that switchboards are so constructed that sufficient space is available for the entry and installation of cables. This point is often overlooked by switchboard builders. It is generally better to connect the outgoing cables direct to switches or breakers than to provide internal wiring from switchgear to terminals. It is recommended that when constructing a switchboard, arrangements should be provided for fixing the cables which have to enter the board. Drilling and welding in a switchboard after it has been erected on board should be avoided as much as possible.

Openings in the bottom plating of a switchboard (or in the floor under the switchboards) must preferably be closed to prevent fires entering or leaving the board via cables and to avoid dirty air entering the board.

Location and construction of a switchboard should be such that no water can enter. The switchboard must be at least drip-proof. Depending on its position on board in view of pipes, flanges, ventilation ducts, etc., further measures must be taken to protect against drip and spray. This point cannot be stressed enough ; many major switchboard faults have been caused by water or steam.

The temperature rise caused by the heat generated in the switchboard must be limited. Good ventilation must be provided. However, more ventilation means more dirt and therefore a switchboard should never be ventilated more than necessary to dissipate the heat. Very few or no ventilation openings are required in a.c. switchboards in which no voltage regulating equipment or lighting transformers or other heat dissipating equipment have been placed. The ideal situation would be to have a totally enclosed, sheet steel switchboard, cooled through ventilating air passing along the outside of the switchboard plating.

Switchboards must be fitted on a foundation which rises above floor level so that no water can enter from the floor. Parts under tension must be well above the floor of the switchboard, e.g. at least 20 cm. When applicable switchboards not accessible at the rear must be provided with a back plate to avoid condensation water or dirt from entering the board via decks or bulkheads.

Switchboards which are open at the rear must be provided

with a space for operation and maintenance. It must be possible to close that space. The rear of such switchboards must be provided with insulated handrails and an insulated mat or grating. Preferably all switchboards must be provided with handrails at the front.

Panels for various voltages and/or currents (d.c. or a.c.) must be separated as far as possible and must be clearly marked. If there are different voltages in one panel, preferably these should be separated and the wiring should be properly marked.

Fuses must be fitted and protected in such a way that they can be replaced under working conditions without any risk of touching parts under voltage. In this respect special attention is to be given to live parts mounted at the innerside of hinged doors, and where necessary such live parts should be effectively screened.

All nuts and screws are to be effectively locked. Following methods can be applied: —

spring washers.

double locking nuts.

special locking nuts.

spring plates.

lacquer for very small screws, adjusting screws, etc.

Locking devices must be fitted immediately under the nut or screw.

Generally not more than two connections to be made on one terminal.

Connections of conductors to be fixed with good quality steel or brass bolts, suitably protected against corrosion.

Contact surfaces of busbars and of apparatus must be smooth and preferably treated with one of the following methods to avoid corrosion: —

tinning.

silver plating.

light coating with acid-free vaseline.

Copper busbars to be fitted free of undue mechanical stress. This can easily be checked by removing a connection and verifying the stress on the bolts and the clearance between the adjacent surfaces.

Protective relays, except when of very robust construction, and electronic parts, if not incapsulated, to be fitted in dust-proof enclosures in the switchboards.

Above the arc chutes of circuit-breakers ample space should be provided to prevent ionized gases leaving a breaker and introducing short-circuits between phases or poles or to earth. If no minimum distances are given in the breaker specification following distances may be applied: —

25 cm from conducting parts.

15 cm from insulated parts.

Breakers should not be installed with their arc chutes right below open busbars.

Ample space must be provided for removal of the arc chutes.

Current transformers should be earthed on the secondary side.

Voltage transformers for measuring and control circuits are also often earthed on the secondary side. If this is not done it is prudent to use transformers with an earth screen between the primary and secondary side to reduce the risk of getting 440 volts on a 220 or 110 volts circuit due to a transformer fault.

To avoid relays or contactors being operated due to earth faults in earthed control circuits, coils of relays and contactors should be connected to the earthed side of the control circuit.

Fuses should never be installed in earthed connections. To ensure easy detection of faults and to allow control and measuring circuits to be subjected to a high voltage test and for measuring of the insulation resistance, it is advised to fit all earthing points of current and voltage transformer circuits on a central earthing busbar which is earthed with a robust copper wire on some points. Hinged doors fitted with current-carrying parts should be earthed with flexible wire connections.

Wiring in switchboard is to be effectively fixed, to be protected against mechanical damages and against chafing on sharp edges.

Openings in metal parts of the switchboards, through which wiring is led, must be fitted with a protection (e.g. rubber or PVC), unless all sharp edges are carefully removed.

Sufficient identification plates to be fitted, e.g. for

—protective devices and their adjusted values.

—fuse ratings for cable and circuit protection.

—current capacity of protected cables, or cable dimensions.

—switches in control and measuring circuits.

—measuring apparatus.

—pilot lamps.

—various other components, such as transformers, regulating resistances, time-delay relays, etc.

All main busbars in the switchboard must be clearly marked with the phase or pole colour or letter.

Fuses for control and measuring circuits must preferably be marked with the phase with which they are connected; this can be done by a colour or letter code or by a logical location in relation to the busbars.

## 5. NOTES CONCERNING SHORT-CIRCUIT CALCULATIONS AND PROTECTION

The available maximum short-circuit is an important factor for the design of an installation. The choice of circuit-breakers, fuses, switches, settings of protective relays and the construction of busbar systems is primarily determined by the short-circuit current to be expected.

The aim of each short-circuit protection system is to limit the effect of a fault. Damage to the system and hazard of fire must be reduced as much as possible and healthy circuits should not unnecessarily be disconnected from the source of supply. Serious short-circuits do occur now and then and the installation should be designed to withstand the effects of it.

To illustrate the fact that such faults do occur the following examples of main switchboard faults have been reported in recent years: —

Ship A: Fault in switchboard. Reason unknown. Diodes in generator excitation circuits found broken-down after the accident. It appeared that the generator breakers had not disconnected the fault but that the fault was interrupted by the failure of those diodes. The generator breakers could not operate because the settings of the delayed short-circuit protection relays were found to be higher than the stationary short-circuit current of the generators.

Ship B: Fault in switchboard due to leakage water. Serious damage was caused in the switchboard because the main breakers had to be tripped by hand. Also here it was found that the generator short-circuit relays had a setting higher than the available short-circuit current.

Ship C: One generator breaker had been taken out of service for maintenance. When putting back in service the crew had omitted to fit the arc chutes. Next time a switching operation was carried out a flash-over occurred between the breaker poles.
This introduced a busbar fault which travelled through the switchboard.
Remaining breakers operated satisfactorily and damage was limited.

Ship D: A main busbar short-circuit was introduced by a loose busbar connection.
Breakers operated satisfactorily and damage was limited.

Ship E: In a d.c. propulsion switchboard a fault between main busbars occurred due to ionized gases coming out of the arc chutes of a manœuvring switch mounted below the busbars. Considerable damage was caused.

Ship F: A heavy short-circuit occurred in a switchboard supplied by two turbo-alternators. One generator breaker opened all right, the second was opened by a very courageous engineer whilst the switchboard was in flames. It appeared later that the second breaker could not operate because the contacts of the short-circuit current relay had too high contact resistance, due to corrosion, and this prevented the breaker tripping coil from tripping the breaker.
The fault was caused by a number of tins with cigarettes and tobacco, found in a withdrawable cubicle type circuit-breaker of a spare switchboard circuit, and which appeared to have been hidden there by a smuggling crew member.

Ship G: A short-circuit occurred in a spare withdrawable starter unit directly connected to the main busbars of a main switchboard.
The reason was the same as mentioned for Ship F. Damage was serious. It was understood that the same had happened before on another ship of the same company having a similar switchboard, also with some spare withdrawable starter units.

Ship H: Due to moisture, dirt and subsequent tracking a short-circuit occurred on the supply side of fuse-holders, fitted in a generator panel. The wiring between the busbars and the fuseholders burnt out.
Further damage was limited.

Ship I: It was alleged that a moulded case circuit-breaker fitted in a main switchboard for the supply of an outgoing circuit had been repeatedly closed on a short-circuit.
Finally, the moulded-case breaker broke down and caused a main busbar fault.
Damage was limited due to correct operation of generator breakers.

All these faults happened whilst the ships were at sea, in one case about 50 per cent of the main switchboard had to be renewed, in other cases the damage was limited, but all faults resulted in a dangerous situation for the ships, giving a black-out for a shorter or longer time and introducing a serious fire hazard.

With the exception of Ship E, all ships had a.c. installations. Fig. 7 shows a picture of one of the switchboards referred to above after the fault had occurred.

The above accidents illustrate the need to give installations an adequate short-circuit capacity, to choose correct settings for protective elements and to ensure that the protective relays are in such condition that they will operate when faults do occur.

It is understood that a paper has been prepared for our Staff Association which extensively deals with short-circuit current calculations.

It is, therefore, not the intention to give here a recipe for such calculations. However, some information regarding fault currents, at least for a.c. systems, will be explained.

To select switchgear and the setting of protective devices the following figures must be known: —

1. **Symmetrical short-circuit current**

   This value is necessary to determine the required breaking capacity of protective devices like circuit-breakers and fuses.
   This current is expressed in kA r.m.s.

2. **Peak asymmetrical short-circuit current**

   This value determines the required making capacity of switchgear. The making capacity is the current that the subject breaker or switch can make safely when closed on a fault. Consequently this value is not of interest for the selection of fuses.
   This current is mostly expressed in kA peak.

3. **Stationary short-circuit current**

   This is the fault current which remains in the circuit when the transient phenomena are over. This value is important for the current setting of a delayed short-circuit protection for generators and major outgoing circuits.
   This current is usually expressed in kA r.m.s.

The short-circuit current which will arise on the terminals of an alternator consists generally of an a.c. component and a d.c. component.

The a.c. component is called the symmetrical short-circuit current. An example of the development of the symmetrical short-circuit current at the terminals of an alternator is shown in Fig. 8.

This figure shows that the short-circuit current has no constant value. Initially the subtransient short-circuit current $J_k''$ arises and this current rapidly changes through a transient period to the stationary short-circuit current $J_o$.

The initial value is determined by the machine subtransient reactance and the decay to the stationary value by the subtransient and transient time constants and the system of voltage regulation. The value of the stationary short-circuit current $J_o$ is mainly determined by the voltage regulation system. The symmetrical short-circuit current arises if at the moment of the fault the short-circuit current would be at its zero value of the sine wave. The short-circuit current can, in that case, build up symmetrical from zero.

If, however, at the moment of the fault the short-circuit current would have its maximum value, a d.c. component will arise forcing the final current, i.e. the current measured on

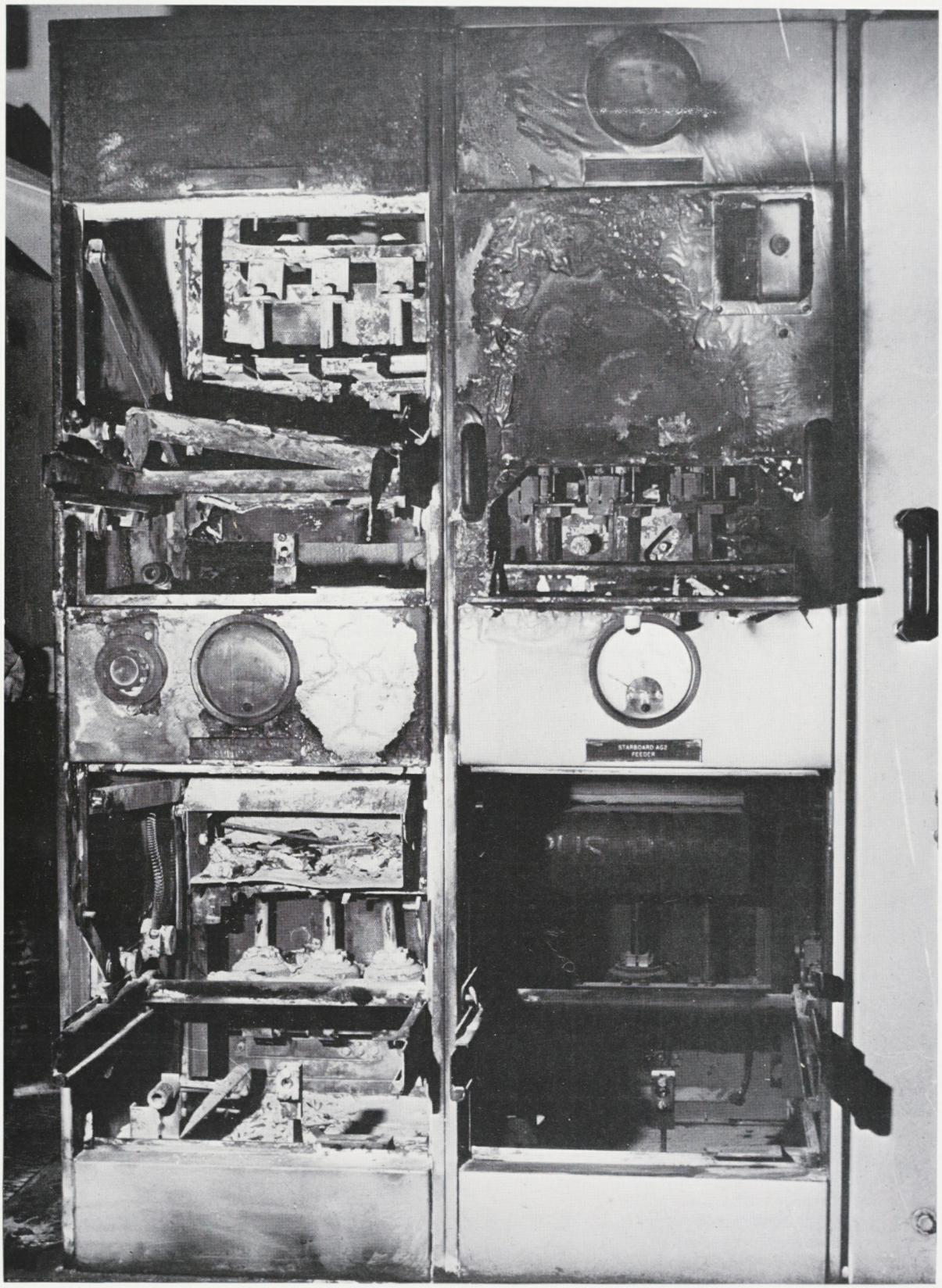



FIG. 7

Main switchboard section seriously damaged by a short-circuit.

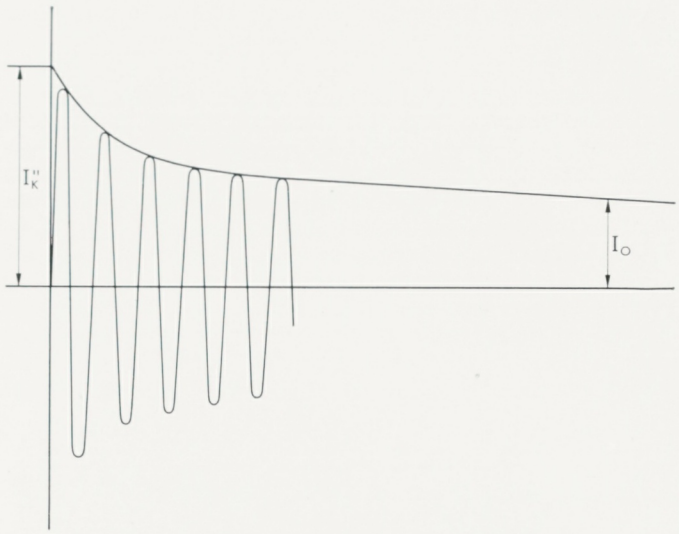



FIG. 8

Example of the development of the symmetrical short-circuit current at the terminals of an alternator.

the terminals, to commence from zero. In that case the asymmetrical generator short-circuit current will develop, consisting of a d.c. and an a.c. component and resulting in the maximum possible short-circuit current. The development of the asymmetrical short-circuit current is shown in Fig. 9.

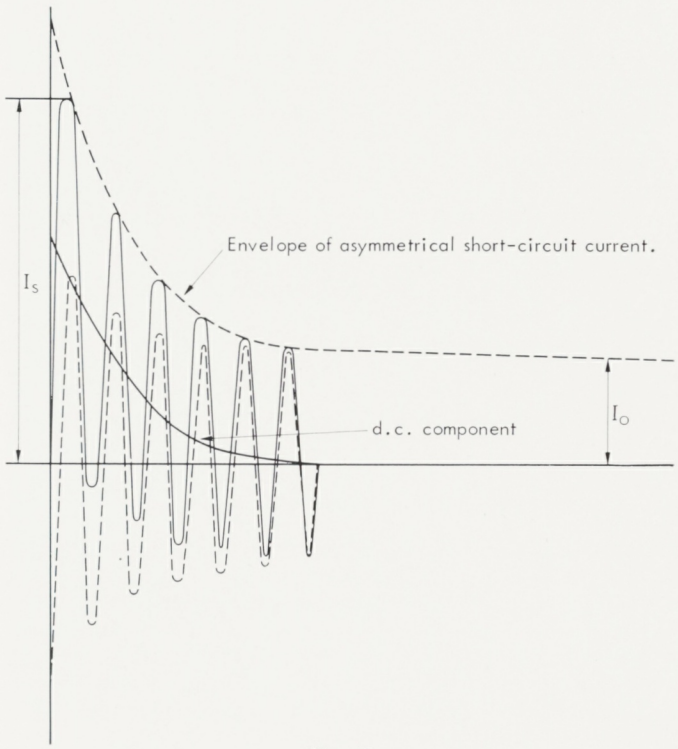



FIG. 9

Development of the asymmetrical short-circuit current at the terminals of an alternator.

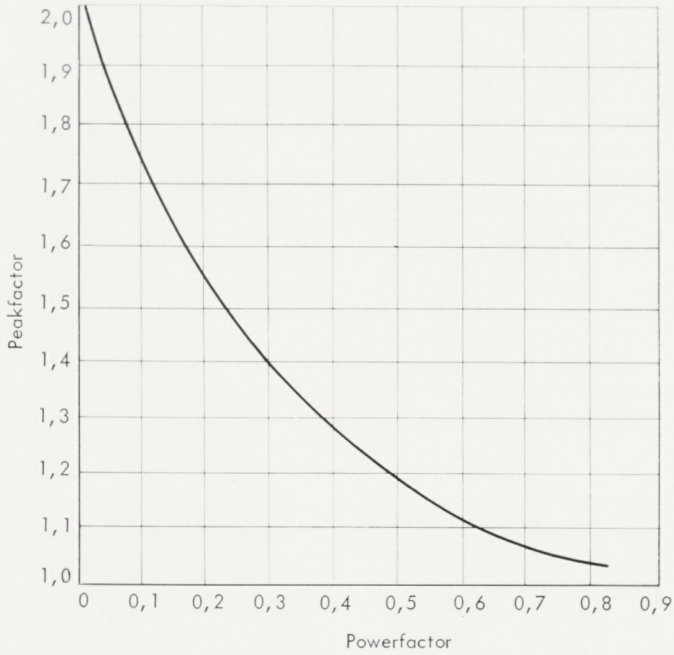



FIG. 10

Peak factor (=doubling factor) versus power factor of the fault circuit.

In this figure it is shown that the asymmetrical short-circuit current is the sum of the symmetrical short-circuit current starting at current maximum, and a d.c. component, exponentially decaying to zero. The time constant of the d.c. component is dependent on the power factor of the circuit in which the fault occurs.

The peak asymmetrical short-circuit current occurs after approximately half a period and is indicated in Fig. 9 as $J_s$. The value $J_s$ can be calculated from $J_k''$ when the time constant (or power factor) of the short-circuit path is known. $J_s$ equals to: peak factor $\times \sqrt{2} \times J_k''$. The peak factor is approximately 1·75 at 0·1 power factor, 1·4 at 0·3 power factor, etc.

Fig. 10 gives the relation between power factor and peak factor (also called doubling factor).

In practice the short-circuit current will normally not be fully symmetrical or fully asymmetrical, but the development of the fault current will be somewhere between the extremes shown in Figs. 8 and 9. In 3-phase systems at least in one phase a current will arise which is more or less asymmetrical.

Choice of circuit-breakers must be based on the most arduous conditions, i.e. the breaker must be able to be closed on a full asymmetrical fault.

The above considerations dealt with fault currents on generator terminals. The same is applicable when calculating faults elsewhere in the system.

The values $J_k''$ and $J_s$ are in that case determined by the combined impedance of generators, cables, transformers, motor feed back currents and power factor of the fault path. For the selection of fuses only the value $J_k''$ has to be known. Both values $J_k''$ and $J_s$ or $J_k''$ and the circuit power factor must be known for the selection of circuit-breakers, particularly for breakers which supply outgoing circuits from main and distribution boards.

The value $J_s$ is also necessary for the design of busbar constructions and for the required making capacity of switches. The value of the stationary short-circuit current $J_o$ is important for the setting of delayed short-circuit protection. A high stationary short-circuit current makes it easy to design a discriminative protection system, i.e. a system which only disconnects the faulty circuit and keeps healthy outgoing circuits from main and distribution boards and, of course, the generator circuits connected.

Another advantage of a "hard" alternator, is their ability to give small voltage drops when squirrel-cage motors are started direct to line.

I.E.C. Technical Committee 18, dealing with Electrical Installations in Ships, recommends that under steady short-circuit conditions the generator with its excitation system should be capable of maintaining a current of at least three times its rated value for a duration up to two seconds, unless protection discrimination requirements allow a shorter duration.

To achieve good discrimination it is often necessary to adjust the short-circuit current protection of generators not far below the stationary value. This, however, implies that the stationary short-circuit current must be known with reasonable accuracy. Experience has shown that for some manufacturers it is difficult to calculate beforehand the stationary short-circuit current of their machines. It is, therefore, considered good practice that short-circuit tests are carried out by the manufacturer on his machines or at least on one of each type and rating. This is also the best method to prove that the requirements of paragraph M 409 have been complied with. Fig. 11 shows an oscillogram of the short-circuit current of a self-regulated compound generator, make

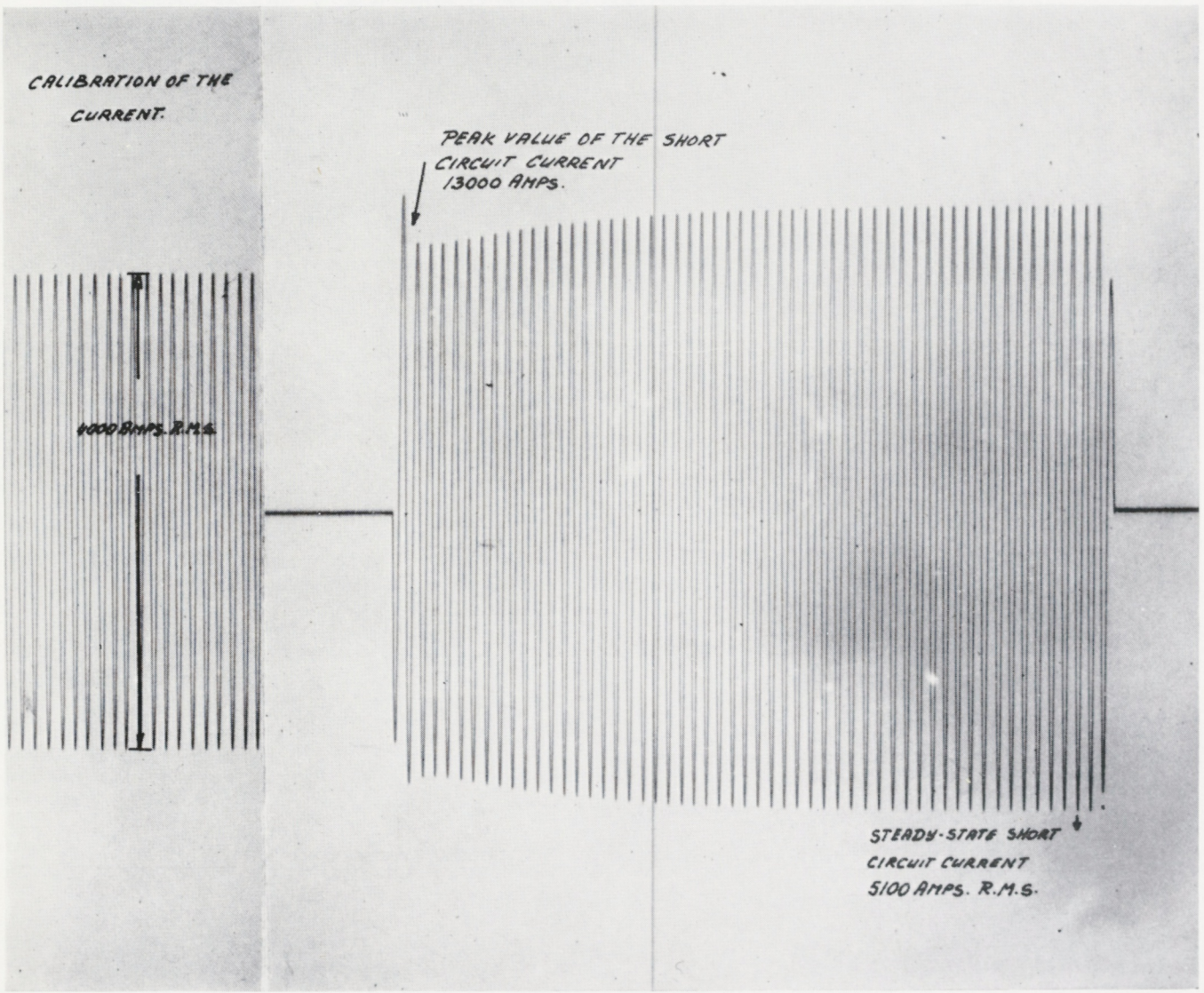



FIG. 11

Oscillogram of the short-circuit current of a self-regulated compound generator.

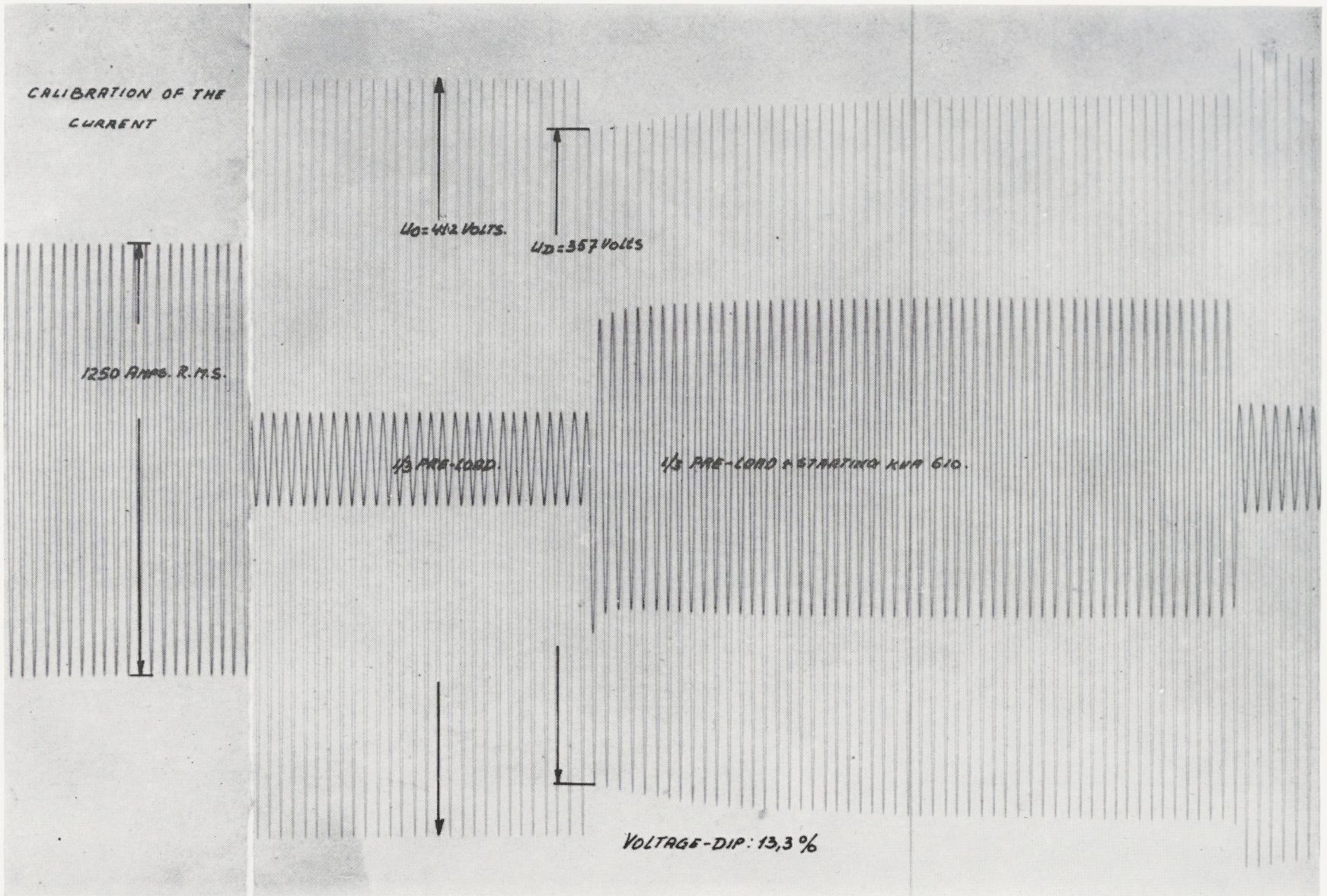



FIG. 12

Oscillogram of the effect of starting of a squirrel-cage motor on a self-regulated compound generator.

Heemaf, type DGC 1130–8, capacity 650 kVA at 415 volts, 50 c.p.s. It will be noted from Fig. 11 that the short-circuit current of this compound self-regulated alternator quickly develops to a stationary value of about 5·5 times its rated current. The value of 13000 amps indicated on the oscillogram is the maximum peak asymmetrical short-circuit current ($J_s$) which may be expected to arise if a full asymmetrical fault would occur at the terminals of this machine. This value has been extrapolated by the manufacturer from the oscillogram shown on Fig. 11.

Fig. 12 shows the effect of the starting (direct-on-line) of an induction motor of 140 h.p. and a starting current of approximately 5 × full load current on the same generator, but with a base load of approximately 30 per cent.

It shows that an alternator with such characteristics makes it possible to start big squirrel-cage induction motors direct-on-line without undue voltage drops.

The short-circuit protection of generators is the final protection of an installation to prevent the generators and the main switchboards from burning out and could as such be considered as the most important protection present in a ship's electrical installation. It must disconnect faults in the main switchboard and faults elsewhere in the system when the other protective devices present in the system would for some reason fail to operate.

It is, therefore, of utmost importance to ensure that these protective devices have the right setting and are in good operating condition. The correct setting of the generator short-circuit protection is determined by the fault current which the machine can deliver and by the setting of protective elements of the outgoing switchboard circuits in order to get the required discrimination. To play safe we would like to choose a low setting of the short-circuit protection, however, this will mostly be prevented by the wish to obtain discrimination.

Paragraph M 609 requires that the protective devices should ensure continuity of service under fault conditions through discriminative action. This means that only the protective element nearest to the fault should operate in order that only the faulty circuit is disconnected. This can be achieved by adjusting the short-circuit protective devices at different current settings and by introducing time delays. The most easy way to obtain discrimination is to use fuses because a fuse of high rating gives automatically a longer operating time at a given short-circuit current. On the other hand with moulded-case breakers it is mostly very difficult and sometimes impossible to achieve discrimination. When three moulded-case breakers are connected in series with magnetic short-circuit relay settings of respectively 1500, 1000 and 500 amps and a fault behind the smallest breaker occurs, resulting in a short-circuit current of 2500 amps, there is a good chance that all breakers will operate. In such systems discrimination is only ensured when time delays are fitted to the two bigger breakers or when the smallest breaker has current cut-off properties preventing the fault current to reach a value in excess of the short-circuit relay settings of the breakers closer to the source. To fit time delays to moulded-case breakers is mostly impossible and when it can be done it must be checked that the breaker is able to withstand the thermal and mechanical effects of the current flowing through the breaker during the delay time.

It is perhaps not superfluous in this respect to note that the rated total break time as mentioned in our List of Type-Tested Breakers is not the delay time but the operating time, i.e. the time between the moment that the short-circuit relay gives a tripping order to the breaker and the moment that the current is interrupted by the opening of the breaker contacts.

The delay time is the time between the moment that the current exceeds the set value of the short-circuit relay and the moment that the relay gives an opening order to the breaker operating mechanism. Consequently the rated total break time does not help to achieve discrimination contrary to the delay time.

When fuses are used it must be realised that fuse operating curves often indicate the total fuse operating time, i.e. the sum of the actual melting time of the fuse wire and the arcing time.

For discrimination the fuse melting time is important because once the fuse wire is melted, the fuse will blow. This is the reason that there is not always discrimination between fuses having ratings of the same order. For instance, the melting time of a fuse-link of 100 amps could be equal or in excess of the total operating time of a fuse-link of 80 amps.

In that case there will be no discrimination between the 80- and 100-amp fuses. Fuse manufacturers are mostly able to supply information concerning discrimination between their fuses.

If that is not available it is a rule of thumb to pass over one step, i.e. not to use a 16-amp fuse behind a 25-amp fuse but a 10-amp fuse, etc.

The easiest and perhaps only way to check on paper whether discrimination will be achieved is to make a discrimination diagram.

Fig. 13 shows an example of such a diagram. It indicates the development of the generator short-circuit current and the tripping characteristics of the applied protective devices. It shows that the generator protection is adjusted at a value below the generator stationary fault current, so that the generator breaker may be expected to operate at switchboard faults, and that the time delays and current settings or fuse characteristics ensure discrimination between generators, outgoing circuits and the circuits from distribution panels.

However, when examining such discrimination diagrams the above mentioned remarks concerning fuses and moulded-case breakers must be borne in mind, otherwise the diagrams could be misleading.

It is further worthwhile to mention that discrimination can be disturbed by instantaneously operating no-volt and under-voltage coils. It is no use to fit time delayed magnetic protection on generator breakers when the no-volt coil is supplied by a.c. and has no delay, because in that case the voltage drop caused by a heavy fault in the installation may trip the breaker instantaneously.

It is, therefore, necessary to provide such breakers with d.c. no-volt coils supplied via a rectifier with a capacitor, or with a mechanical retarder fitted to the no-volt trip mechanism.

It has been argued above that delay times, particularly for generator circuits, are necessary to achieve discrimination. However, these delay times should be as short as possible because: —

(a) When a busbar fault occurs the fault current will flow during the whole delay time, during which considerable damage can be caused by arcing, etc.

(b) During the delay time parallel running generators can fall out of synchronism because during the time that

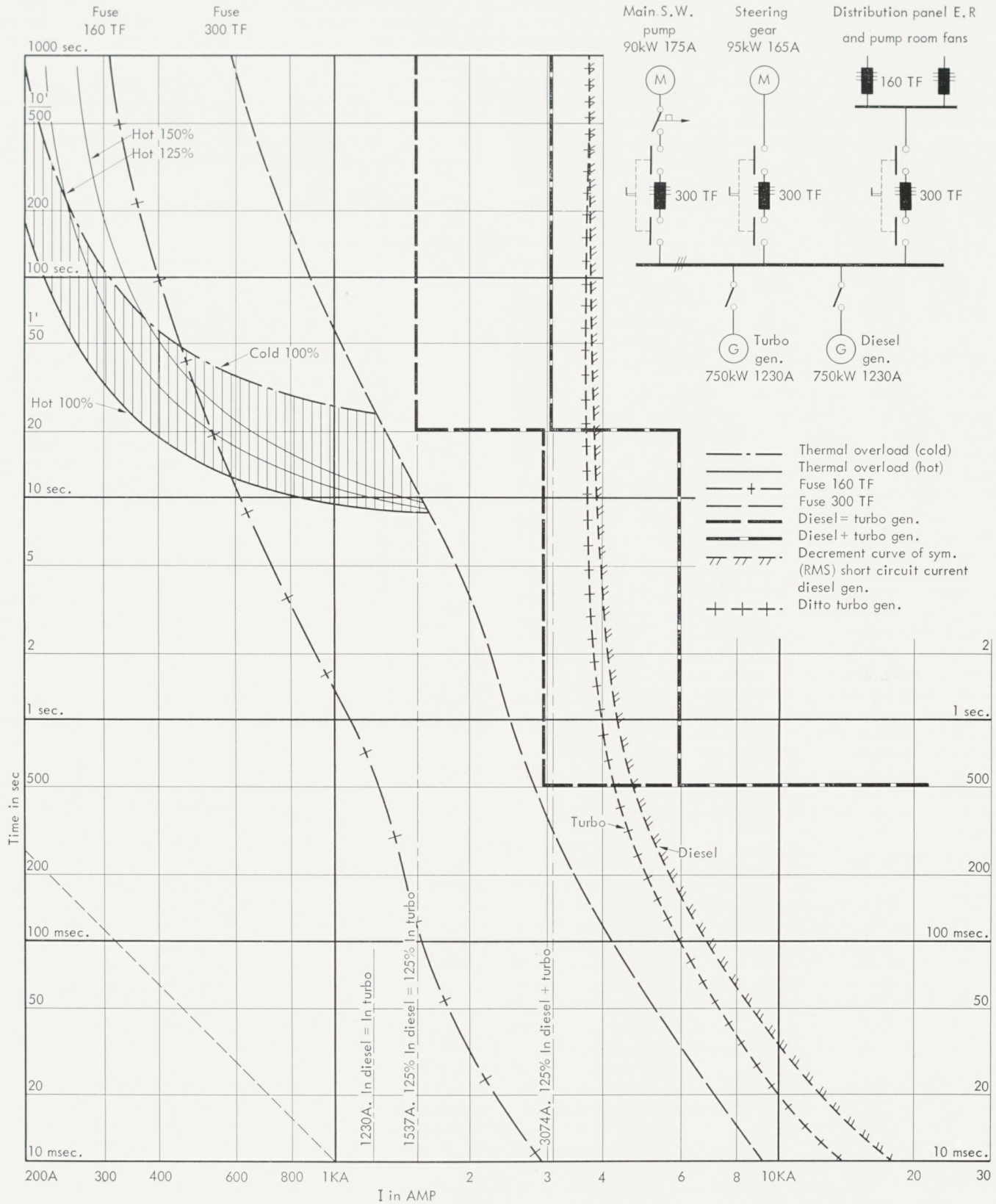



FIG. 13

Example of a discrimination diagram of protective devices.

short-circuit currents are flowing the coupling between the generators is weak.

Therefore delay times connected to the short-circuit protection of generators should not exceed 0·4 or 0·5 seconds. In installations with more than two generators running in parallel, the generator breakers are sometimes also provided with an instantaneously operating short-circuit relay, adjusted at a value considerably higher than the setting of the delayed short-circuit protection. The purpose of that protection is to disconnect a generator instantaneously from the main switchboard in case a fault occurs inside that generator or between that generator and the switchboard. Such a fault will be supplied by the remaining generators and the feed-back from motors. The current so obtained will exceed the setting of the instantaneously operating relay, whilst the short-circuit current of the generator itself is only sufficient to operate the delayed short-circuit relay. Such a system ensures a discriminative action of the protection when faults in outgoing circuits occur and ensures an instantaneous operation when faults in the generator circuits occur.

Fuses supplying squirrel-cage induction motors must be selected in order to withstand the starting current of the motor. When the motors are started direct-on-line this could mean that the fuse rating must be 1·5 up to 2 times the motor current rating. When large motors are installed it is often difficult to achieve discrimination between the generator protection and the fuses of the motor circuit. In such cases it is sometimes worthwhile to use special back-up fuses instead of normal distribution fuses.

The typical characteristics of back-up fuses are to operate very fast when high fault currents occur, and to operate very slow at low overcurrents. As such fuses are, in fact, not designed to interrupt overload currents it is essential that such fuses when used for circuit protection are accompanied by overload relays, either in the motor starter or in the switchboard. Unlike normal distribution fuses, back-up fuses are not suitable to protect supplies to distribution panels.

Back-up protection (by means of fuses or circuit-breakers) is sometimes provided to protect one or more other protective devices present in the system, but having insufficient short-circuit current making and/or breaking capacity.

When this practice is followed care should be taken to ensure that:—

(a) It is clearly shown that the protective device with insufficient capacity is suitably protected by the back-up protection. Generally this information is difficult to obtain.

(b) When the protective devices of a number of circuits are installed behind one common back-up protection, these circuits do not include very essential groups like steering gear motors, main lighting circuits, etc. Otherwise one faulty circuit could lead to loss of power to such essential consumers.

These points do not make it attractive to use back-up protection.

The best method to ascertain that the protection system operates correctly and ensures discrimination is to carry out short-circuit tests on board.

Details of short-circuit tests recently carried out on two new-buildings are shown on Figs 14 and 15. Fig. 14 shows an installation for three generators, each of 435 kVA, 440 volts, 60 c/s, 570 amps, 348 kW. The maximum symmetrical short-circuit current per generator is 3·2 kA and the stationary short-circuit 2·3 kA.

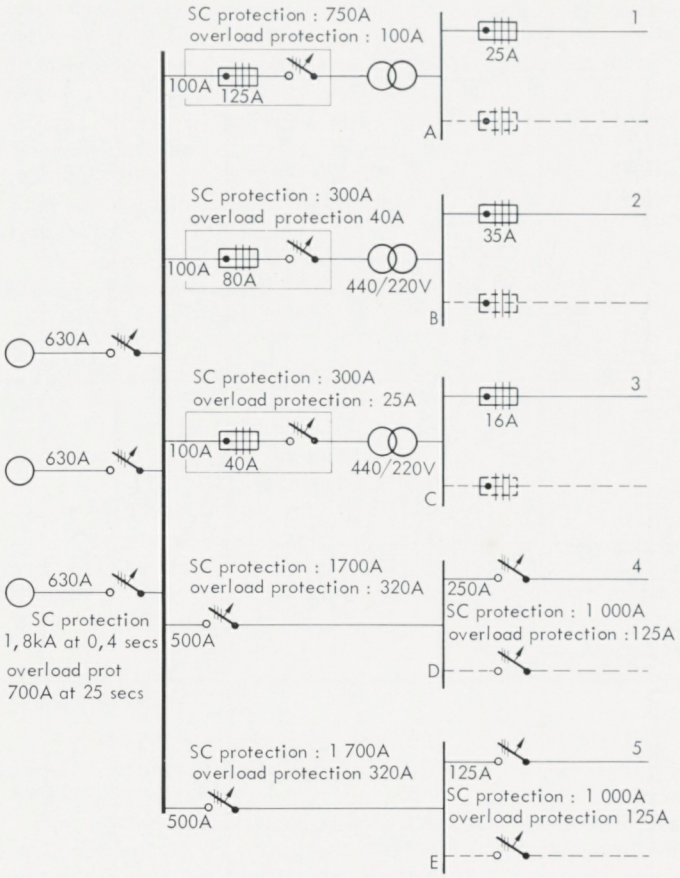



FIG. 14

Schematic diagram of an installation in which short-circuit tests were carried out to check discrimination of protective devices.

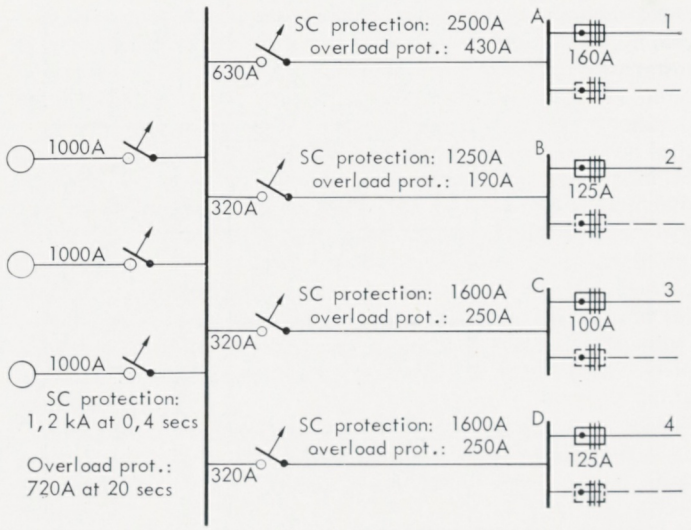



FIG. 15

Schematic diagram of an installation in which short-circuit tests were carried out to check discrimination of protective devices.

All tests were carried out with two generators running in parallel as this was expected to be the normal condition for the ship. The main busbar fault level under those conditions was estimated to be 9·0 kA symmetrical and 22·0 kA peak asymmetrical. Distribution board E is supplied via long cables and the symmetrical fault on that panel was estimated to be 6·0 kA. The circuits A, B and C are supplied via moulded-case circuit-breakers with built-in back-up fuses. The circuits supplying D and E have moulded-case breakers without back-up protection.

The circuits supplied from A, B and C are provided with fuses, those supplied from D and E with moulded-case breakers. The breaker ratings, fuse ratings, short-circuit and overload settings are shown on the figure. The faults were made at the points 1, 2, 3, 4 and 5. In cases 1, 2 and 3 only the fuses near the faults opened, leaving all other circuits healthy. In cases 4 and 5 not only the breakers near the faults opened, but also the breakers fitted on the main switchboard. In all cases the generator breakers stayed closed. Consequently it appeared that there was no discrimination between the breakers on the main switchboards and those fitted on distribution panels D and E.

The three generators shown on Fig. 15 have each a capacity of 440 kVA, 0,8 power factor, 440 volts, 60 c.p.s., 590 amps. The maximum symmetrical short-circuit current per generator is 2·1 kA and the stationary short-circuit current 1·4 kA. All tests were carried out with two generators in parallel.

The main busbar fault level under those conditions was estimated to be 5·0 kA symmetrical and 12 kA peak asymmetrical. All circuits supplying A, B, C and D have moulded-case breakers whilst the circuits supplied from those panels have been provided with fuses. All ratings and settings are shown on the figures. The faults were introduced at the points 1, 2, 3 and 4. In all cases not only the fuses near the faults operated, but also the breakers on the main switchboard. The generator breakers did not trip. Consequently there was no discrimination between the breakers on the main switchboard and the fuses fitted on the distribution panels.

The short-circuit tests described above were intended to check correct operation of the protective devices and discrimination and not so much to check whether the subject installations were able to withstand the effects of the maximum available fault currents. The short-circuits were introduced by heavy switches and arcing was prevented. In practice, however, most faults will not be "bolted" faults but will be introduced by incidental contact between poles or phases due to loose wires, faulty insulation materials, etc. Such faults will be accompanied by arcing.

Fig. 16 shows a photograph taken during a short-circuit test carried out on an a.c. switchboard in the test station of Messrs. Kema, Arnhem, Holland. At this test the fault was deliberately so introduced that arcing could occur between the phases and to the earthed switchboard plating. The photograph shows how the arcing travelled through the board along the bare busbars. The available power was 35 kA r.m.s., 550 volts, during 0·3 seconds. The power factor of the short-circuit path was approximately 0·15. This photograph clearly illustrates the amount of destructive power available in an installation with a short-circuit capacity of this order.

Generator circuits must also be provided with overload protection. The overload protection must protect the generator against damage due to sustained overloads. An often chosen setting is 125 per cent with a time delay of 20 or 30 seconds, although higher settings will also be found depending on motor starting currents. It must, however, be realised that in most cases the prime mover of the generator, particularly diesel engines, will not be able to deliver the overload level adjusted at the protection device. Most diesel engines will not give more than 110 per cent and that only under favourable conditions and when the engine is not too old.

It is, therefore, often said that the best overload protection for a generator is its driving engine. However, for installations with parallel running a.c. generators the overload protection is essential because it will protect the generator against the effects of high wattless currents which can occur when, for some reason, the wattless load sharing between the generators is not in order. This could, e.g. be caused by a defect in an excitation or voltage regulation system. The wattless currents will not ask kilowatts from the driving engines, which will therefore not be overloaded by such faults.

Preference tripping systems, required in installations with parallel running generators, serve a different purpose than generator overload protective systems. The overload protection must protect the generator against overheating and will therefore disconnect the generator from the system, mostly resulting in a black-out. The preference tripping system on the other hand must prevent black-outs. The setting of the preference tripping relay must, therefore, be selected to match the capacity of the combination of the generator and its prime mover. Generally the required setting will, therefore, be much lower than the overload protective relay setting. Considering the very limited overload capacity of diesel engines it is, therefore, prudent to choose a setting not much in excess of 100 per cent. This consideration makes it clear that it is a bad practice to give the overload and preference tripping relay the same setting and to adjust only the time relays at different values.

As the preference tripping relay setting must match the capacity of the combined generator set it is a good practice to operate the preference tripping system from a watt relay rather than a current relay, at least with a.c. installations. In that way the prime mover would be prevented from overload caused by loads with high power factors which will not necessarily trip the preference tripping current relay. Some systems employ a combination of a current and a low frequency relay to operate the preference tripping system. Such a combination has the same advantage as a watt relay and does, moreover, prevent a black-out when a prime mover is in bad condition and would lose speed without being overloaded. Time delays in preference tripping relay should be short, e.g. 3 to 5 seconds because, as said before, the overload capacity of many prime movers is limited.

This is easily understood when it is realised that a good preference tripping relay should prevent a black-out when one out of two parallel running generators fails.

Assume that before the fault the generators were each on 75 per cent full load, when one generator fails the other gets 150 per cent full load. But, in addition, the failing generator will draw reverse power from the healthy machine until the faulty set is disconnected from the busbars by the reverse power protection. Diesel engines can easily take 20 or 30 per cent reverse power and consequently the healthy generator is temporarily loaded up to 180 per cent full load.

Another consequence of this consideration is that auxiliary relays used in preference tripping systems should not be voltage sensitive. The 180 per cent full load on the healthy

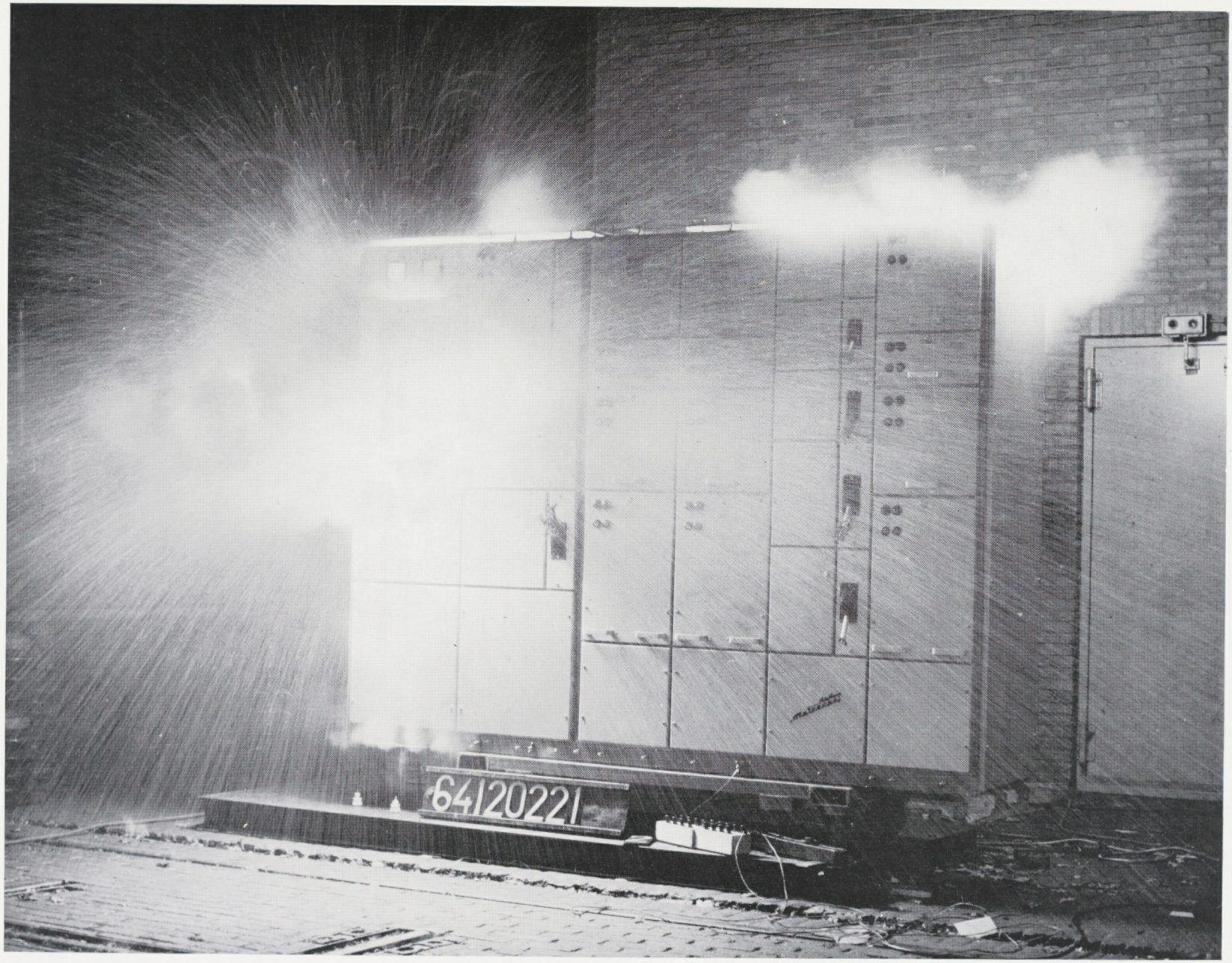



FIG. 16

Short-circuit test carried out on a switchboard in a test station.

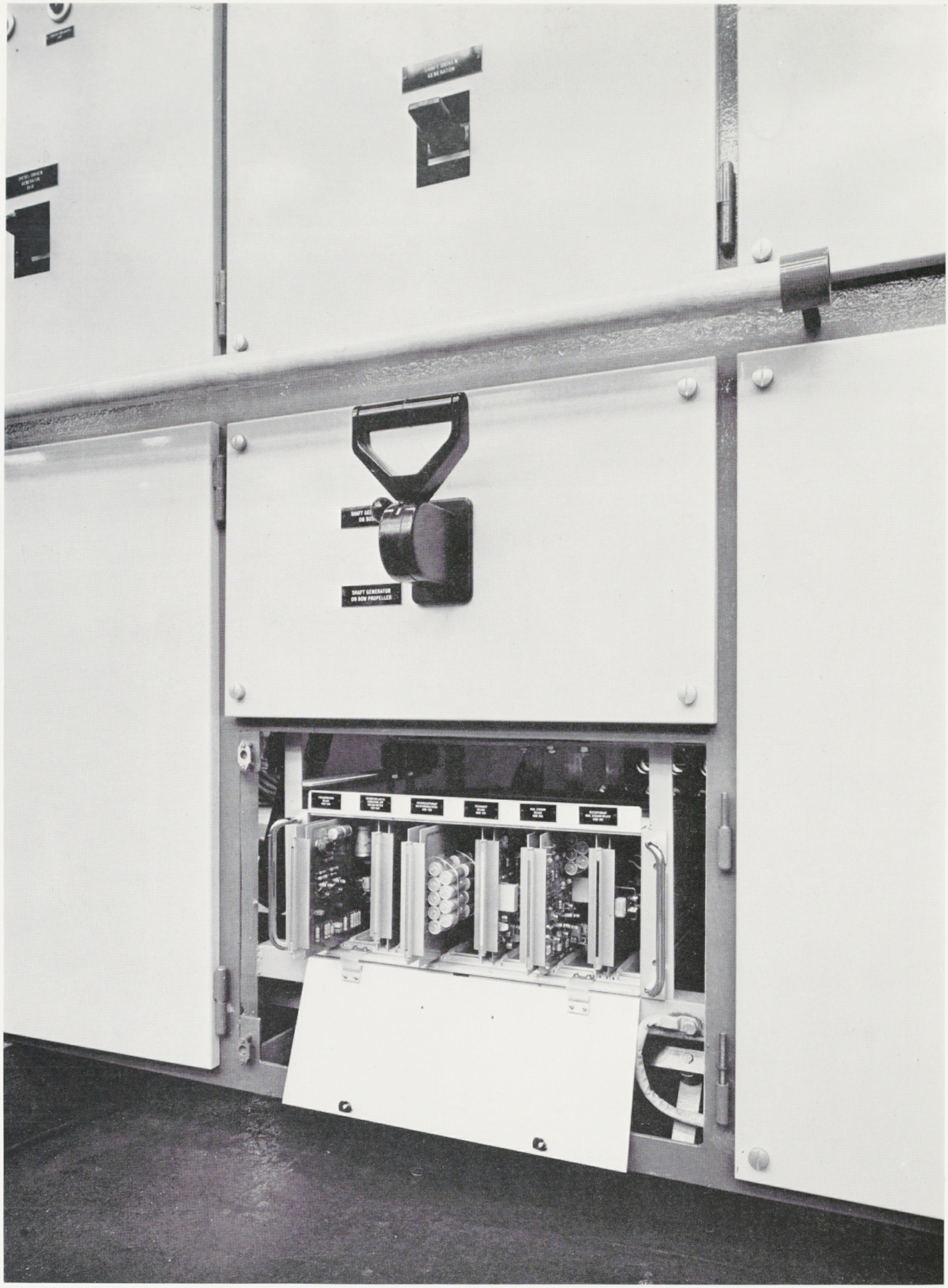



FIG. 17

Part of generator panel with electronic generator protection.

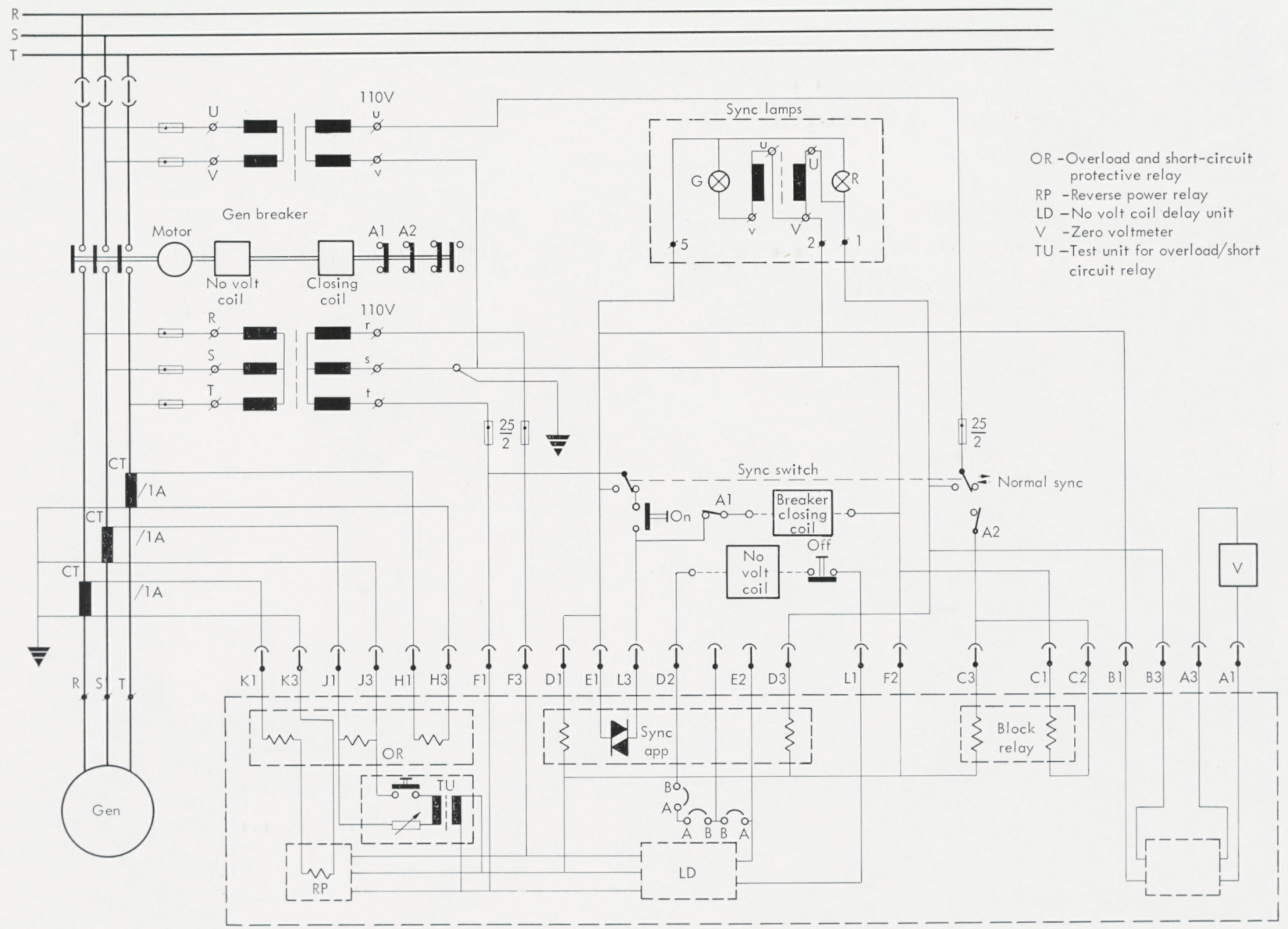



FIG. 18

Schematic diagram of generator circuit with electronic protection system.

machine will most probably cause a serious voltage drop and this lower voltage should not prevent the preference tripping system from operating.

Again the best method to check whether the preference tripping system operates satisfactorily is to carry out a test under full operating conditions, e.g. during the sea trials.

Although our Rules require preference tripping systems only in installations with parallel running generators, it is also useful to install such systems in ships intended to operate with one running generator, at least when under some operating conditions the load could be in excess of one generator, e.g. due to faults of the operator.

For all protection systems employing magnetic relays, etc., it is important to check the difference between the trip and the reset value of the relay. In most cases this difference should be small and should not prevent the system to be fully loaded. A preference tripping relay tripping at 110 per cent should reset at 100 per cent or more. Otherwise it could happen that the relay is tripped by a sudden current rise, e.g. due to a starting current, and that in spite of the fact that the current decreases to below 100 per cent before the time adjusted at the time relay has elapsed, all circuits connected to the preference tripping system will be de-energized. Similarly, black-outs could occur when the difference between tripping and resetting of overload relays is too large.

In earlier days only direct-acting protective relays, fitted on circuit-breakers and directly operating the breaker tripping mechanism, were used.

Nowadays indirect operating protective relays are becoming more and more popular. Such relays can be supplied by current transformers and trip the breaker via no-volt or trip coils. Many switchboard builders prefer indirect protection systems because it is often easier to achieve discrimination, the system is more flexible, adjusting and testing is easier and adjusting ranges can be made to suit every particular purpose.

Fig. 17 shows a photograph of a generator panel with built-in electronic generator protection.

Fig. 18 gives a schematic diagram of this panel, and Fig. 19 a picture of the printed circuit cards and their enclosure. This particular system was developed some years ago by Messrs. Van Rietschoten and Houwens, of Rotterdam. The system includes printed circuit cards for overload and short-circuit protection, automatic synchronizing and manual synchronizing equipment, reverse power protection, no-volt coil supply and delay equipment and built-in test equipment for the overload and short-circuit protection.

Similar equipment has been developed for the preference tripping system operating on current and frequency, kilowatt relays for starting stand-by generators and automatic load sharing equipment.

The printed circuit cards are provided with safety systems to prevent a generator breaker from closing when the printed circuit cards containing protective relays are not in position.

Fig. 20 shows a discrimination diagram of an installation provided with this protection system. A special feature of this system is that the overload and short-circuit protections are

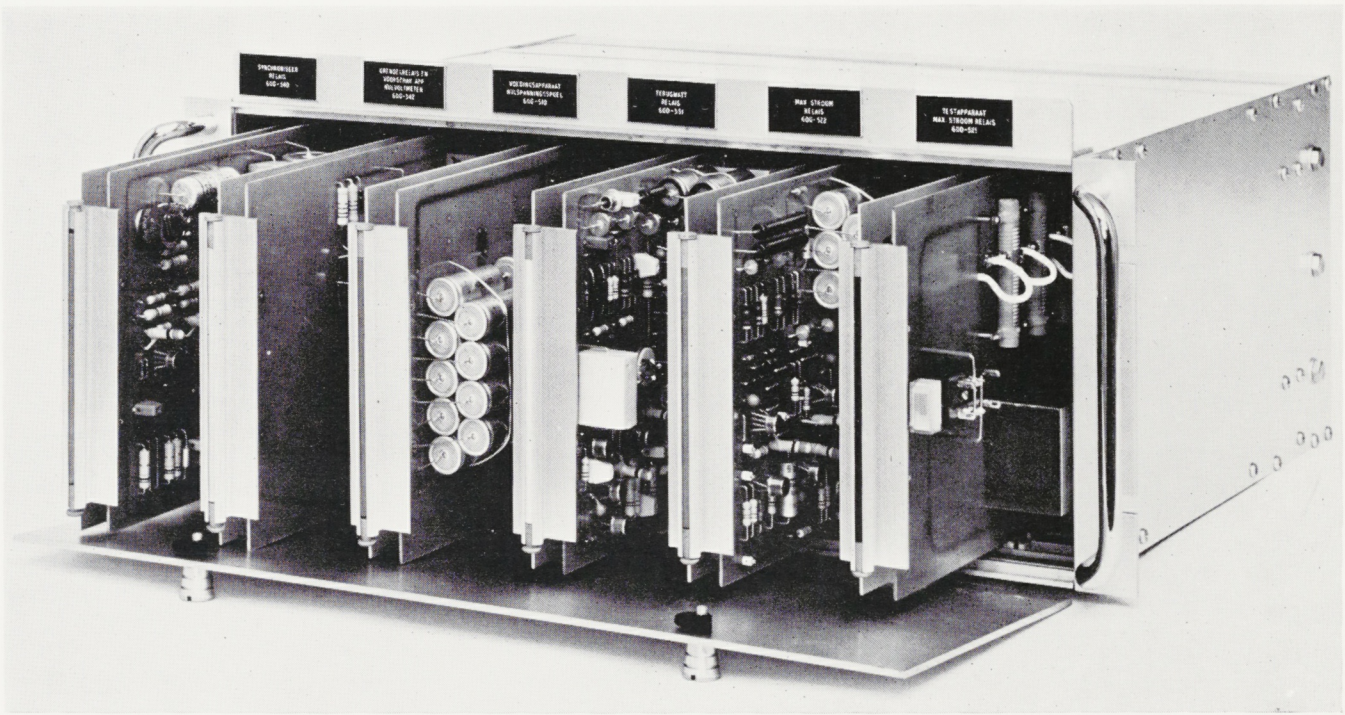


FIG. 19

Printed circuit cards of electronic generator protection.

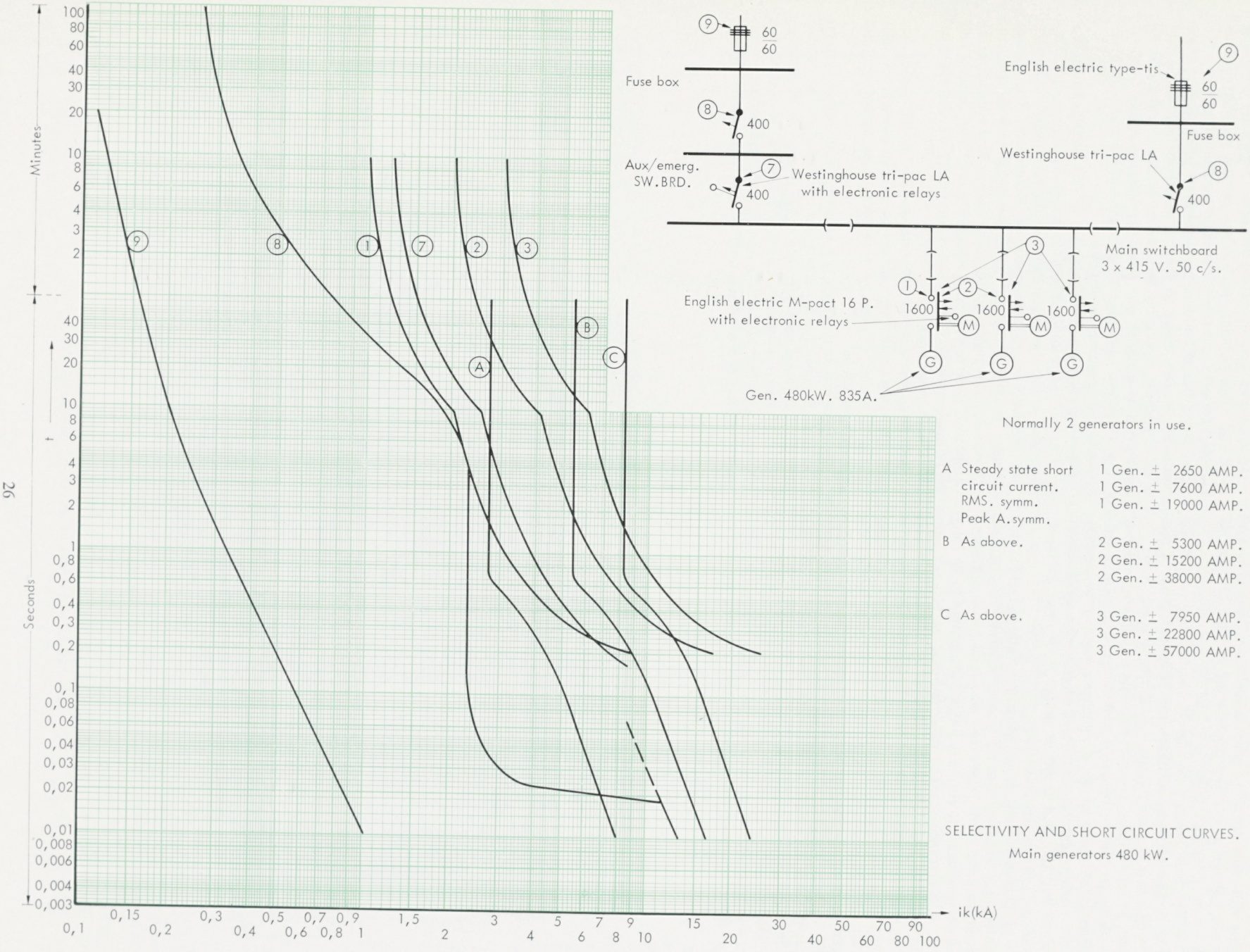



FIG. 20

Discrimination diagram of system incorporating electronic overload and short-circuit protection.

combined and that the resulting characteristics of that protection is very similar to a fuse characteristic; consequently discrimination between large fuses and the generator protection is easily obtained.

When indirect operating overcurrent protection systems are used, care should be taken to ensure that the relays are capable of withstanding the maximum possible short-circuit currents. For instance a preference tripping relay adjusted at, e.g. 800 amps should not be damaged by the maximum possible short-circuit current, which could be 25 kA in the particular system.

Contactors, as e.g. used in motor starters, centralized starter panels, group starboard boards forming part of the main switchboards, etc., should be properly protected against faults so as to prevent contact welding, undue arcing and possible flash-overs between phases or poles. Usually this protection is provided by fuses and due to the current cut-off characteristics of fuses at high fault currents this arrangement usually ensures a good protection. However, care must be taken when contactor circuits are protected by circuit-breakers. The energy let through by circuit-breakers at short-circuits, even when the breakers have been provided with instantaneously operating protective devices, is often more than the contactor can withstand. In that case the breakers have to be replaced by fuses or extra back-up protection has to be fitted.

## 6. MOTOR CONTROL GEAR

Since d.c. installations have been largely superseded by a.c. installations, motor starters have become much simpler. A starter for the straight-forward control of a squirrel-cage induction motor may only consist of an isolating switch, a contactor, an overload relay and some push-buttons and control current fuses.

However, the introduction of automatic motor starters, used e.g. in unattended engine rooms, and provided with interlock, auto control, alarm, signalling, remote control and other facilities, has changed the picture and again made starters quite complicated.

The following points may be borne in mind when considering motor starters, centralized starter panels, etc.

It is important that sufficient means of isolation is fitted in motor supply circuits, to safeguard personnel carrying out maintenance or repairs to motors, their driven auxiliaries and motor starters.

The most favoured method is to provide an isolating switch in the motor starter panel or unit. It is not necessary then to fit an extra isolating switch near the motor, although this is recommended in cases where the motor is not located in the same compartment as the starter. In accordance with Rule requirements such remote isolators must be lockable in the "off" position.

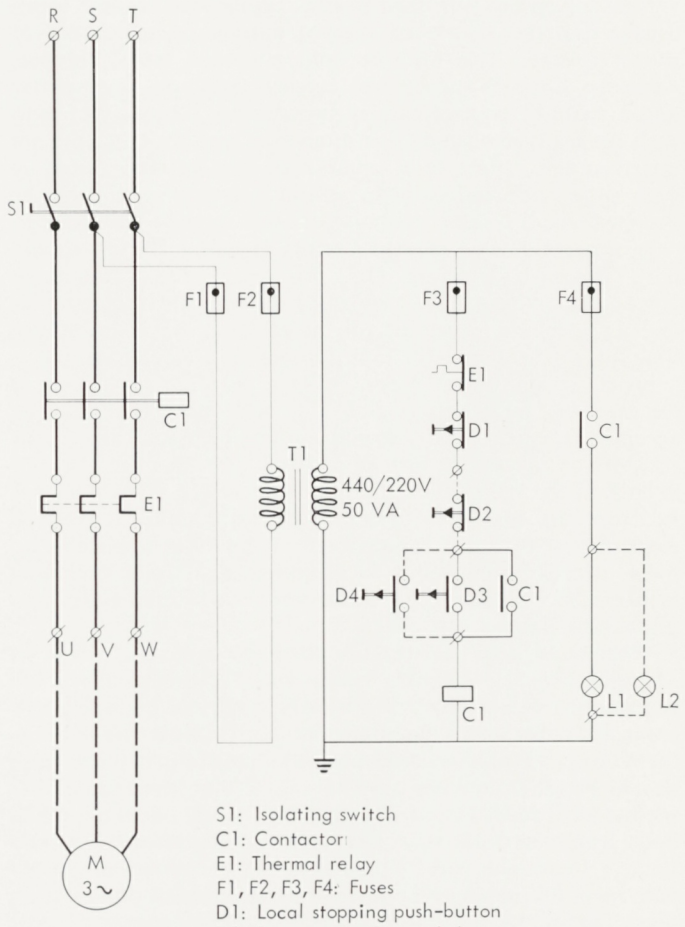
In most starters the control circuits (contactor coil, auxiliary relays, etc.) are supplied via a control current transformer at a voltage of 220 or 110 volts. When all auxiliary wiring and associated equipment has been mounted inside the starter there is no objection against the use of 440 or 380 volts for the supply of the control circuits, provided all equipment is adequately rated for the subject voltage.

However, when auxiliary wiring is connected to external equipment, particularly thermostats, pressostats, etc., or to remote control switches mounted in central control desks, control voltages exceeding 250 volts should, in the Author's opinion, preferably not be used in view of safety of personnel. It is understood that some National Authorities do not allow the use of voltages in excess of 250 volts in such cases.

The protection of control current transformers and their associated circuits does often appear to be very difficult. This is due to the limited capacity of such transformers. Fig. 21 shows a typical diagram for a simple a.c. motor starter. The control current transformer is protected by 2-amp fuses on the primary side and the two secondary circuits, one for control and for signalling lamps, are also protected by 2-amp fuses.

When the transformer has a capacity of 50 VA and a short-circuit ratio of 5 per cent the following could happen.

The rated currents are approximately 0·115 amps on the primary side (440 volts) and 0·230 amps at the secondary side (220 volts). The 5 per cent short-circuit ratio will result in the following maximum short-circuit currents available when a




S1: Isolating switch
C1: Contactor
E1: Thermal relay
F1, F2, F3, F4: Fuses
D1: Local stopping push-button
D2: Remote stopping push-button
D3: Local starting push-button
D4: Remote starting push-button
L1: Local running lamp
L2: Remote running lamp
T1: Transformer

FIG. 21

Schematic diagram of a.c. motor starter.

fault would occur behind the transformer: —

Primary short-circuit current: 2·3 amps $\left(=\frac{100}{5}\times 0{\cdot}115\right)$

Secondary short-circuit current: 4·6 amps $\left(=\frac{100}{5}\times 0{\cdot}230\right)$

The current time characteristics of the 2-amp fuses will show that the primary fuses will never operate and that it is even doubtful whether the secondary fuses will protect the transformer against burning out. When the fuses would have higher ratings, or the transformer have a capacity of 25 instead of 50 VA, the fuses can never protect the transformer and consequently every fault in the secondary circuits would cause the transformer to burn out and possibly cause damage to other parts of the starter panel or centralized group starter board. It must, therefore, be ensured that control current transformers are not too small and their fuses not too big or, in other words, that their protection is satisfactory.

It is sometimes proposed to use one control current transformer for the supply of control current to a number of starter circuits. This may be done provided individual protection is fitted in the control current supply to each starter and a stand-by control current transformer is available. With such an arrangement it is ensured that one fault would not interrupt the supply to a number of motors. Of course, in such cases main and stand-by essential services should not be supplied via the same common control current transformer.

In general control current circuits in motor starters should have separate protection. Only for small motors can it be considered that the fuses, protecting the motor circuit, provide also an adequate protection for the control circuits, i.e. starter internal wiring, contactor coil, remote control circuits, etc.

Signal lamp circuits should have a separate protection as required by paragraph M 618. For such circuits it may be accepted to use other current-limiting devices, like series resistors or capacitors, instead of fuses, provided the result of a fault in the lampholder, lamp or connecting wires does not interrupt the supply to essential control circuits. It may be remembered that this requirement is not only applicable to motor starter circuits but to all essential circuits, including bridge control systems, generator control systems, alarm and protection systems, etc.

When automatic starters are used the system is often so arranged that the stand-by pump starts automatically when the running pump fails. This mostly results in quite a lot of control circuit wiring common for both motor circuits, e.g. the wiring to a pressostat, to a central control panel, etc. Care should be taken in such cases to ensure that one fault (loose wiring, local short-circuit, damaged switch, etc.) does not make both pumps inoperative. Cases have been reported where one fault in a common part of the motor control system prevented both main lubricating oil pumps or other essential pumps from operating. Some of the sophisticated motor starter systems now in use are perhaps too complicated and instead of making machinery installations safer they rather make them less reliable.

In order to overcome this problem it may be necessary to provide each automatic motor starter with an emergency switch. In case of a fault in the common part of the system, each motor can be individually started via the emergency switch, at the same time disconnecting all wiring to common selector switches, pressostats, remote control stations, etc.

Another problem with automatic stand-by motor starters is that sometimes control circuits in the starter unit of pump motor 1 are supplied from the starter unit of pump motor 2 and reverse. Consequently not all the circuits of such starter units will be de-energized if the isolating switch in power supply to one starter is switched off. To safeguard personnel, it is prudent to fit a warning plate inside such starters or an extra isolating switch.

Finally, it should be ensured that after black-outs not all automatic starters will start simultaneously, overloading the generator by their starting currents. A sequential starting system should be provided in such systems.

Each motor should be provided with adequate overload protection, interrupting the supply to the motor in case of overload. An exception, of course, should be made for the steering gear motors which should have short-circuit protection only and an overload alarm. The same philosophy could be applied to bow thruster motors, as these motors could also be considered as steering gear motors.

The characteristics of the overload devices, e.g. thermal overload relays, should match the overload capacity of the protected motor. As now mainly C.M.R. (Continuous Maximum Rating) motors are used it is necessary to adjust the overload relay at a value of 100 per cent of the current rating. When this would offer problems due to starting currents this should not be solved by adjusting the relay at a higher setting but by using an overload relay with a more suitable current-time curve. For motors driving machines with long starting-up times like purifiers, ventilating fans, etc., special overload protection systems have been developed. Some of those systems employ saturated current transformers which restrict the contribution of the starting currents to the heating of the thermal relay, others employ time relays which disconnect the overload relays during the starting period.

However, where such delayed overload protection systems are used, it should be ensured that the motors are suitable to withstand the excessive heating caused during the prolonged starting time. A few cases have been reported recently where boiler fan and purifier motors had been burned out because the motors could not carry the starting current during the long starting periods.

Where overload alarm relays, as used in steering gear motor circuits, do not interrupt the current, they should be able to carry the overload current for a prolonged period, unless the relay is disconnected from the circuit after it has operated the alarm.

It is strongly preferred that thermal relays used for motor protection are of a temperature compensated type, i.e. that the effect of ambient temperature is compensated. This is particularly important when the centralized starter board is located in an air conditioned control room and the protected motor is mounted in a hot part of the machinery space. When the thermal relay and the protected machine have the same ambient temperature, temperature compensation is not so important.

Overload relays should protect motors against single phasing, i.e. against the effects of higher winding currents which can arise when one of the phases of the motor supply is interrupted.

This is particularly essential when the motor windings are delta connected, because in a delta wound motor the winding currents are not equal to the current measured by the over-

load relay in the supply line. When the motor windings are star connected the winding currents are equal to the currents measured by the thermal relay and consequently a star connected motor is more easily protected against single phasing.

Motor circuits are usually controlled by contactors. Contactors are specially designed to deal with starting currents, e.g. a contactor rated for a 100-amp motor will be able to close regularly currents up to 600 or 800 amps, depending on the ratio between rated current and starting current. Switches and circuit breakers, although they could have a high current making capacity, are usually not designed for that duty.

Consequently damage must be expected when switches or circuit-breakers are regularly used to start motors. It is therefore not acceptable to use switches or circuit-breakers for the control of motors, unless they are designed for it and due consideration has been given to the effects of the starting currents.

The use of thermistors or similar devices inserted in the windings of a motor and intended to disconnect the motors in case overheating due to overload occurs, is becoming more and more popular. In particular, for motors for intermittent duty as bow thrusters, winches, etc., their use can be recommended.

The disadvantages of this system are: —

(1) Some have only fixed settings so that readjustment is impossible.

(2) Testing is virtually impossible unless there is an opportunity (and permission) to overload the machine.

It must further be ascertained that the motor is fully protected by the thermal elements under all circumstances, including when a start attempt is made whilst the rotor is blocked.

The system should as far as possible be failing to safety, i.e. interrupted wiring to the motor or inside the motor to the elements or supply failure of the control unit, should operate the protection and disconnect the motor, or preferably sound an alarm.

## 7. CABLES

During the last decennium a revolutionary development has taken place in the field of marine cables. Some ten years ago the use of natural rubber and varnished-cambric insulated, lead-sheathed and steel-wire or cotton-braided cables was still very popular and such cable constructions are now no longer used. Since that time we have seen the rapid rise of butylrubber and polyvinylchloride (PVC) as insulating materials and polychloroprene (neoprene), chlorosulphonated polyethylene (CSP or Hypalon) and PVC as sheath materials. Now the development continues with the fast introduction of ethylene-propylene rubber (EPR) and cross-linked polyethylene (XLPE) as new insulating materials.

It is perhaps worthwhile to mention some of the typical properties of the insulating and sheath materials now mainly used.

The insulating materials butyl, EPR and cross-linked polyethylene are vulcanised or cross-linked materials. Butylrubber and EPR are "rubberlike" materials, i.e. they are elastic and mechanically not very strong. Both materials, but particularly butyl sometimes give problems to cable manufacturers because of deformation of the insulation during the process of cable making. The effect of such deformation is eccentricity of the conductor insulation causing a substantial difference between the minimum insulation thickness and the average or specified value. The mechanical characteristics of butyl and and EPR make it impossible to use those materials in very thin layers as is done with PVC or other materials. Although cross-linked polyethylene is not a thermoplastic material like PVC, the mechanical characteristics are similar to those of PVC, i.e. mechanically strong, not very elastic and the material can be applied in thin layers. Butyl and EPR are not resistant against oil; in an oily atmosphere both materials may soften and lose their mechanical characteristics. Cross-linked polyethylene is better resistant against oil than butyl or EPR. All three materials can be sufficiently resistant against ozone, provided the right compounds are used. Recently some cases of damage were reported because butylrubber compounds had been used which were insufficiently resistant against ozone. This resulted in cracks on the insulation at the cable ends, i.e. on places where the protective sheaths of the cables had been removed and were not replaced by sleeving or taping.

The electrical characteristics of butyl, EPR and cross-linked polyethylene are excellent and result in high insulation resistances measured on cables insulated with those materials. They have also good temperature characteristics and good ageing properties.

PVC is a thermoplastic material. At low temperature it becomes hard and brittle whilst at high temperatures it softens. This behaviour is quite different from that of butyl, EPR and XLPE. Those materials are good at low temperatures, particularly butyl and EPR, while high temperatures will only accelerate the ageing.

PVC insulated cables may not be installed when the temperature during installation is lower than a certain value, e.g. 5°C, because otherwise the insulation would be too hard and brittle with subsequent danger of damaging it at bends, at bulkhead penetrations, etc. This acceptable minimum installation temperature is dependent on the particular PVC compound and must be stated by the manufacturer.

Also due to the temperature characteristics, PVC insulated cables are more easily damaged by welding, burning or similar accidents during the building of the ship.

Whilst with butyl or EPR insulated cables the local high temperature often only affects the cable outersheath, unless the accident is really serious; in case of PVC insulated cables, there is a good chance that small accidents of this nature will also damage the insulation. PVC has sufficient resistance against oil and ozone. The electrical characteristics are also satisfactory but not as good as those of butyl, EPR or XLPE.

The materials polychloroprene and chlorosulphonated polyethylene are both very suitable to be used for cable sheathing. They have good resistance against high temperatures, ozone and oil. The mechanical properties are excellent. Their electrical characteristics are rather poor but, of course, this is of no importance for cable sheath materials.

The existing I.E.C. publ. 92–3 referred to in M 851 of our Rules, contains recommended characteristics for butylrubber, PVC and polychloroprene, such as requirements for tensile strength, elongation, ageing tests, thermoplastical characteristics, etc. The next edition of I.E.C. publ. 92–3, now being prepared, will also include material specifications for EPR, XLPE and CSP.

There is much similarity between butylrubber and EPR although the thermal capacity of EPR is considered to be somewhat better than that of butyl. It is expected that the new specifications for EPR insulated cables will mention the

same insulation thickness as for butylrubber but will allow 85°C as maximum conductor temperature whilst this is 80°C for butyl. It is further expected that the specifications for cross-linked polyethylene insulated cables will allow the same insulation thickness as for PVC insulated cables, but at a maximum conductor temperature of 85°C.

The recommended material characteristics for CSP sheath materials will be about the same as those for polychloroprene. With regards to cables insulated with cross-linked polyethylene it has appeared that the ageing performance of certain XLPE compounds is affected by copper catalysis and therefore the copper conductors should be tinned or other measures taken to prevent this.

For the present it is not the Society's practice to have cables inspected and tests witnessed at the manufacurer's works.

The specifications for the various cable types made by the different cable makers are examined by Headquarters, approved, when in order and the cables are usually not seen before being delivered to the shipyards. Also, type tests are normally not witnessed.

Maker's Test Reports can be requested from the builders, but mostly those Reports do not contain much useful information.

It is, therefore, worthwhile to inspect the cables at the yard, at least as far as possible. Accurate measurements of insulation and sheath thicknesses cannot be taken without laboratory instruments and also material characteristics cannot be determined.

However, a visual examination can show whether the general make-up and construction of the cable is in compliance with the applicable specification, the insulation and sheathing has been applied in concentric layers, conductors have been tinned when required, braidings or armourings have not damaged inner and/or outer sheathings, etc. It is further important that the sheathings can be easily separated from the insulated conductors and the insulated conductors from each other, otherwise the insulation could be damaged at the cable ends during finishing of the cables.

Not all manufacturers provide their cables with a proper marking. Many new cable types were recently introduced or are now being introduced, using a variety of materials and sometimes with different temperature classes. The marine cable market is moreover very international. Without proper identification it is, therefore, not easy for a Surveyor to check that cables of a known and approved type and of adequate ratings are being used.

Drum identification is not always accurate as labels get lost during transport or labels from earlier orders are still on the drum. Further drum identification cannot help when the cable has already been installed on the ship. It is, therefore, the Author's opinion that all cables should be provided with a suitable marking from which the essential details like type, insulation material, factory, etc., can be determined. As all equipment including fuses, small terminals, relays, etc., are provided with name plates, or other means of identification, it is not quite understood why the electrical industry makes an exception for such important items as cables.

Many marine cables now used have no metal braiding or armouring and, of course, no lead sheath. When in earlier days almost all cables had a metal sheath the condition of a cable could rather easily be determined by the measurement of the insulation resistance between the conductor(s) and the earthed metal sheath, in particular with single-core lead-sheathed cables used in d.c. installations. For a modern cable having, e.g. a butyl conductor, a polychloroprene inner sheath and a PVC outer sheath this method is quite useless. If, therefore, for some reason, e.g. due to fire or water damage, the electrical insulation of such cables have to be carefully checked, the insulation resistance must be measured between the various conductors of the cable and not only between the conductors and earth.

Our Rules do not contain specific requirements for internal wiring of switchboards, starter, etc. Also I.E.C. publ. 92–3 does not include recommendations for internal wiring. In some countries National specifications for marine wiring have been drafted like the German specification DIN 47704.

It is the Author's practice to require, in principle, the following for internal wiring: —

(a) Insulation thickness and current rating to comply with our Rules for cables.

(b) Wiring to be flame retardant.

(c) Conductors to be stranded.

(d) Wiring should be suitable for an ambient temperature of about 65°C, as due to the presence of heat dissipating equipment inside panels the temperature can be expected to be often higher than the maximum ambient temperature of 45°C.

(e) Outer sheath or the insulation itself (when no extra sheath is present) to be suitably strong to prevent damage due to chafing or otherwise where the wiring is in contact with metal or other switchboard parts.

(f) The materials to comply with the material specifications of I.E.C. 92–3 or with another suitable national or international specification.

The above does not apply to wiring in control or monitoring consoles used for low voltage and low power circuits. In such consoles lighter wiring may be used provided it is suitable for its particular application.

The machinery installations of many ships are now provided with extensive alarm, data logging and similar monitoring systems. The amount of cables on board ships is considerably increased by this development.

The voltage and current used in those instrumentation and monitoring systems are mostly very low. It is, therefore, quite logical that special cables have been and are being developed for those circuits, with smaller dimensions and of lighter construction.

Such general instrumentation cables can, e.g. be built up as follows: —

Tinned copper conductors, stranded and with a cross-sectional area of 0·5 or 0·75 sq. mm. Conductors insulated with 0·5 mm of a suitable insulation material, e.g. cross-linked polyethylene or PVC.

The insulated conductors in pairs combined to form the final multi-core cable.

Sheath of, e.g. polychloroprene.

Metal braiding. } Optional.
Outersheath of, e.g. PVC. }

Not all constructions of this type of cable have a metal braiding, but in view of possible interference between different circuits it is preferred to have a braiding, which serves as a screen.

It is sometimes proposed to use such cables not only for alarm and instrumentation circuits, but also for essential control circuits, like generator control, motor starter circuits,

bridge control, steering gear control circuits, etc. Although the official voltage rating of the cables in question may be adequate for such circuits, it is the Author's opinion that this should not be done, or at least not before sufficient experience with such cables has been obtained. In this respect reference may also be made to the requirements of M 810 for cables exposed to voltage surges associated with highly inductive circuits.

## 8. SELECTION AND INSTALLATION OF CABLES

This subject is extensively dealt with in Chapter M of the Rules. However, the following additional remarks may also be of interest.

Where, in way of the cables, the ambient temperature is very high, heat resisting cable or heat resisting wiring in metal pipe has to be used. This may apply to boiler rooms, the vicinity of auxiliary boilers, on diesel engines, near galley ranges, etc. The heat resisting cable can be of mineral insulated type (pyrotenax), silicone rubber insulated or of an equivalent type. The heat resisting wiring can be a special wire like aircraft wire with a glass braiding over PVC or silicone rubber, asbestos insulated wiring, etc. In this respect it may be noted that silicone rubber is mechanically very weak and should not be used without the protection of a proper sheath.

Cables for installations which are sensitive to interference such as radio and gyro installations, certain electronic measuring, control and alarm installations, etc., should be provided with an efficient metal screening and should preferably be installed separately from other cables, i.e. not in the same conduit or under the same clip on a cable tray. Earthing of the screens should be carried out in accordance with the instructions of the manufacturer of the electronic equipment.

Cables on engines and on all other locations where serious vibrations may occur, should have stranded conductors.

It is sometimes proposed to use one multi-core cable for the connection of several circuits, instead of employing one cable for each individual independent circuit. This is, of course, quite in order when it concerns a multi-core cable from a junction box on a diesel engine to the control desk in the control room, connecting all alarm circuits from the diesel engine to the central alarm panel. If, however, such a proposal concerns complete separate systems, care should be taken.

It is, in the Author's opinion, not acceptable to allow the use of one multi-core cable to supply the forward navigation lights, anchor lights, fog-horn and other essential circuits. Essential independent circuits should have individual cables.

When cables are laid in bunches care should be taken to ensure that all cables have sufficient ventilation. This, of course, only applies to power and lighting cables and is not applicable for cables of measuring, remote control and other low-current systems.

Cables carrying currents up to their full load rating should not be bunched together in more than two layers, or it should be ensured otherwise that the cables are sufficiently surrounded by free air for ventilation.

M 814(a) requires that a correction factor of 0·85 is to be applied where more than six cables belonging to the same circuit (carrying the same current) are bunched together. Although the subject is extensively mentioned in the Rules (M 843) it is perhaps not superfluous to note that sufficient attention has to be given to the use of single-core cables in a.c. circuits.

In view of the possibility that eddy currents arise, single core a.c. cables should not be surrounded with, or close to, magnetic materials like steel and iron. The eddy currents created in the magnetic material due to the presence of an electromagnetic field originating from the a.c. current, may cause local overheating, with the subsequent danger of damage to the cable or other equipment. Particular attention has to be paid in this respect to gland plates for single-core a.c. cables, fitted on connection boxes of machines and switchboards. Such gland plates should not be made from steel but brass, pertinax or another non-magnetic material.

All cables should at least be of flame-retardant type (M 812) i.e. fires should not be spread through a ship via cables.

However, ship's fires have occurred where it was positively found that the fire was spread by the cables, in spite of the fact that the cables were of a flame-retardant type. This can be explained by: —

(a) Tests to determine flame retardant characteristics are carried out on one sample of a cable. In a ship one cable bunch can contain ten or more cables, secured under one clip. When a cable is found to be flame retardant it does not necessarily mean that ten of such cables clipped together are also flame-retardant. In fact, tests on some cable types have proven that it is much more difficult to give ten cables bunched together flame retardant properties than one cable.

(b) Cable runs are painted and, after some years, covered with a layer of dirt, oil, etc. This is an additional condition which shows that the flame-retardant test is not quite representative of the actual conditions during a fire on board.

In view of this it is important to provide as many fire stops as possible in cable systems. This can, e.g. be realised by filling non-watertight bulkhead penetrations with a mixture of asbestos-cement or another suitable compound. This does not necessarily apply only to real fireproof bulkheads or decks (such as engineroom bulkheads, bulkheads between holds and accommodation) but also for accommodation bulkheads and decks, engine room 'tween decks, bulkheads in engine rooms separating auxiliary enginerooms, purifier rooms, boiler rooms, etc.

For the same reason cable entries to switchboards, distribution boards, control rooms, etc., should preferably be made to serve as a fire stop for burning cables.

The usual method to secure cables to cable trays and cable supports is to use stamped galvanized steel clips or similar metal accessories. When the size and shape of the clip is properly matched to the cable bunch this method does not present any problems and results in an excellent job.

Some builders favour the use of galvanized pre-punched flexible steel strip from which the fitter makes clips on the spot. Also with this system satisfactory results can be obtained, however the following points must be watched: —

(a) Spacing of the pre-punched holes is fixed; so the clip can only have a certain number of fixed positions. This means that only by coincidence the clip fits; most of the time it is either too small or too large. In practice it is usually found that the clips are too small and the cables are pressed together. This does not matter for a substantial cable with an armouring, braiding or strong non-metallic outersheath, but may be unacceptable for cables without a strong outersheath, such as some types of cables used in small power, lighting and instrumentation circuits.

(b) Due to the presence of the pre-punched holes the pressure on the cable is not the same in different places under the clip. Where there is a hole the available surface is less and this causes high local pressures. Again this is not important for strong cables but must be watched for lighter cables.

A practice becoming rapidly popular is the use of special nylon and PVC patent straps to secure cables. Several types of these materials are available such as Colson, Insuloid, etc. The principle is that a plastic strap is tightened around the cable bunch and fixed by some sort of patent locking device. Fig. 22 shows a photograph of cables secured with Colson straps.

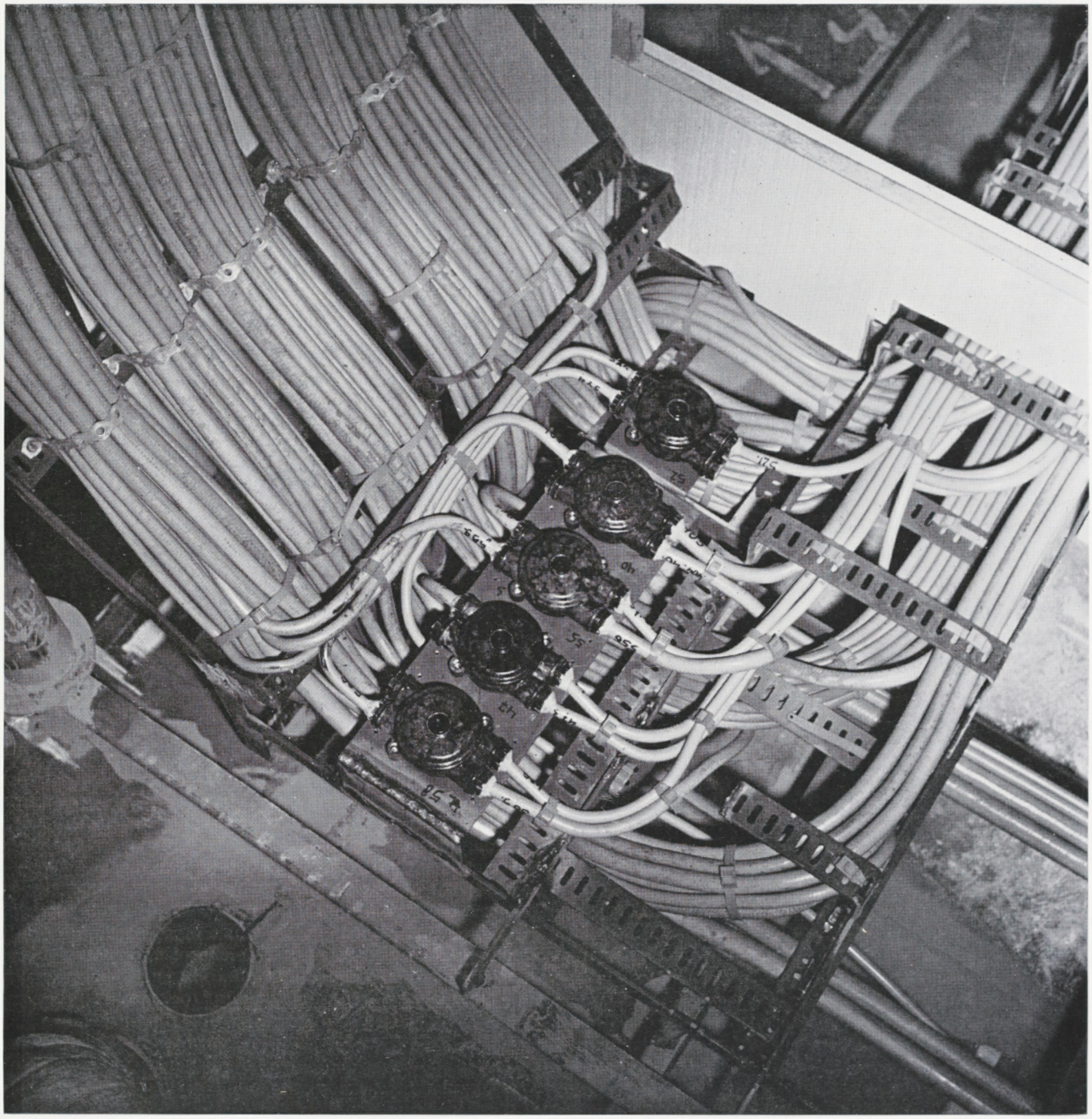


FIG. 22

Cables secured with nylon Colson straps in accommodation alleyway.

The following points have to be watched when such systems, employing non-metallic cable clamps, are applied:—

(a) Cables should be properly secured for the lifetime of a ship. It is definitely not acceptable that after, say, ten years, cabling systems should have to be renewed because of loss of mechanical characteristics of plastic clipping materials due to unforeseen ageing, ambient temperatures, oily atmosphere, ozone, etc. It is, therefore, thought necessary that some experience is obtained before such systems can be accepted without any restrictions.

(b) Nylon or PVC cable straps are not fireproof. When cables are attached to cable trays there is a danger that when a small local fire occurs, the straps burn off and the burning cables may fall from the cable tray and spread the fire.

(c) When using plastic cable straps it is often difficult to make a proper bunch. Because the material is mechanically weak and flexible the cable bunches will be round instead of rectangular and this may prevent all cables being sufficiently ventilated.

In view of the above the following practice has been arranged with the Dutch contractors:—

(i) For cables hanging on cable trays or mounted to vertical cable supports metal clips should be used at regular distances (approximately 1 metre for heavy cables and 1·5 to 2 metres for light cables) in addition to the Colson or similar straps.

(ii) When the cables are lying horizontally on top of cable supports no extra metal clips are necessary except at places where heavy cables have been bent.

(iii) Care should be taken to ensure that the cable bundles are so composed that all cables, carrying current, are sufficiently ventilated.

(iv) Such cable clipping systems are not to be used on open decks or similar non-enclosed spaces.

In accommodation spaces the lighting and similar equipment is frequently supplied through insulated wiring in pipes instead of by cables fitted on cable trays. There is usually one central junction box fitted in each cabin or compartment, supplied by a cable from a distribution box. From that junction box all further wiring to switches, lamps, socket outlets, etc., is laid in pipes fitted behind panels and ceilings. Excellent results may be obtained with this system provided the following points are duly taken into account:—

(a) The pipes should preferably be of insulation material, such as PVC, and are to be properly fixed. In the Author's opinion steel pipes are not very suitable for this purpose because the unavoidable sharp edges may damage the wiring.

(b) The insulated wiring must be of good quality, e.g. 660 volts grade switchboard wirings. In Holland and Belgium the type of wiring normally used for this system is 750 volts grade butyl insulated and PVC sheathed switchboard wiring. There is, however, no reason why similar good results could not be obtained when a good PVC insulated wiring is used. The wiring should further be stranded.

(c) It should be ensured that the piping system is uninterrupted in order that the wiring is well protected throughout and does not come in contact with wooden panelling, steel bulkheads, etc. In this respect special care should be taken at the places where the horizontal pipes behind the ceilings meet the vertical pipes fitted behind the bulkhead panelling and where the pipes enter connection boxes for lamps, switches, etc.

Where pipes are used for the fitting of cables the following points may deserve attention. The pipes must be galvanized internally or otherwise efficiently protected against corrosion It should not be possible for water or oil to accumulate in cable pipes. If, with this in view, holes are drilled in the pipes, care should be taken that the inside of the holes have no burrs which may damage the cable sheaths. For evident reasons the holes should be drilled before the cables are in position. Because such drainage openings often get choked by dirt and rust it is better to provide one large opening at the lowest point of the pipe than to drill small openings at regular distances.

When long cable pipe systems are used, sufficient pulling boxes should be fitted. Between those pulling boxes there should be only a limited number of bends. In vertical cable pipes the pulling boxes should be provided with means to fix the cables in order that the cables are not damaged by the weight of their own length. Where expansion can be expected, such as on tanker decks, the pipes should be fitted with expansion bends or expansion joints. Expansion joints should also be fitted in cable pipes to winch motors, to allow movement of the motor during winch operation. When cables are being fitted in pipes the heavy cables should be drawn in first in order that light cables are not damaged.

The finishing of cable ends in switchboard, connection boxes, etc., deserves close attention as this is quite often the most critical part of the erection of a ship's electrical installation. As emphasized in earlier parts of this paper all connections should be properly tightened and provided with effective locking arrangements. It is also important that the cable should be adequately finished and the risk of damage to insulated conductors and connections reduced to a minimum. There should be no mechanical load on connections, i.e. the cable should be properly clipped near each cable termination. This is particularly important where the equipment is installed on anti-vibration mountings. When patent cable shoes such as Burndy or AMP are used, it should be ensured that the right sizes are used and that no strands of a conductor have been cut off to make the cable shoe fit. Also, the right tools should be used to ensure that a compression type socket is adequately fitted to the conductor. When cables enter terminal boxes, switchboard or panels through watertight glands it is generally essential that no outer sheaths have been removed from the cable outside the watertight gland. Also, inside the panels it is good practice to leave the cable undisturbed as far as possible.

The insulated conductors of a finished cable should be well protected against mechanical damage or other hazards. For cable with a hygroscopic insulation, like varnished-cambric, it is essential that the cable ends are properly sealed and the insulated cores sleeved or taped. The modern materials like butyl, PVC, etc., are not hygroscopic and for that reason sealing of the ends is not necessary.

However, many cable constructions use fillers or cotton tapes around conductors and where those materials are hygroscopic the cable ends should also be properly dealt with to prevent ingress of moisture into the cable. PVC or cross-linked polyethylene insulated conductors need not be taped or sleeved at the cable ends because those materials are con-

sidered to be sufficiently oil-resistant and mechanically strong.

When butylrubber or EPR is used as insulation it is prudent to provide the cable ends with taping or sleeving as those materials are not oil-resistant and not mechanically strong. Taping also reduces the ageing and the risk that the insulation is affected by ozone. Particularly in terminal boxes of motors and generators the cable ends should be properly dealt with as on those places space for the cable ends is usually very limited resulting in short bends and mechanical stresses on the conductor and its insulation. When the machines are running the cable ends may also be subjected to vibration and higher ambient temperatures. It is always advisable to prevent insulated conductors of cable ends from coming into contact with metal construction parts of terminal boxes and panels. Where this cannot be avoided it may be considered to provide additional insulation.

It may finally be noted that useful information concerning choice and installation of cables is contained in Chapter XI of I.E.C. publ. 92–3.

## 9. ELECTRICAL INSTALLATIONS ON OIL TANKERS AND OTHER SHIPS INTENDED TO CARRY CARGOES REPRESENTING DANGER OF EXPLOSIONS

The specific requirements for tankers and similar ships are extensively dealt with in our Rules and Instructions. However, it might be worthwhile to mention a few additional points.

M 1603 mentions a list of areas in which explosion danger exists. This does not mean, however, that automatically all other places are safe and suitable for the location of any part of electrical equipment. In particular the 3 m Rule for equipment on open deck should be used with extreme care.

The high loading and unloading velocities obtained with modern pumping installations, either on board or on the tanker terminal, result in large quantities of gas being produced. It is, therefore, probably more realistic to consider the whole open deck of a tanker as dangerous. In this respect it may be interesting to take note of the recent proposals from an I.E.C. Working Group dealing with electrical installations on tankers. In accordance with these proposals the following spaces are to be considered as dangerous: —

(a) Cargo tanks.

(b) Cofferdams adjacent to cargo tanks.

(c) Cargo pump rooms.

(d) Enclosed or semi-enclosed spaces immediately above pump rooms or above vertical cofferdams adjacent to cargo tanks unless separated by a gastight deck and suitably ventilated.

(f) Spaces, other than cofferdams, adjacent to and below the top of a cargo tank (e.g. trunks, passage ways and holds).

(g) Zones on open deck, or semi-enclosed spaces on open deck, within at least 3 m (10 ft) of any oil tank outlet, vapour outlet or cargo tank.

(h) Zones on open deck over all cargo tanks including wing ballast tanks to the full width of the vessel plus 3 m (10 ft) fore and aft on open deck, up to a height of 2·4 m (8 ft) above the deck.

(i) Compartments for cargo hoses.

(j) Enclosed or semi-enclosed spaces having a direct opening into any of the spaces or zones mentioned above.

On some ships socket outlets for 110 or 220 volts are installed on open deck, mainly for the supply of portable lamps. Although such socket outlets are installed outside the 3 m zones this must be considered as a very bad practice. The socket outlet itself will already present an explosion danger but even more dangerous will be the flexible cables to the lamps or other equipment. With reference to M 1610 it is sometimes possible to prevent such sockets being installed, although formally the Rules do not prohibit this practice. Perhaps the safest method for lighting of dangerous spaces is to make use of air-driven lamps with pressurised enclosure. With this system an air-driven turbine, a small generator and a lamp have been put together in one enclosure. When connected to the ship's working air system the turbine drives the generator which supplies the lamp. When the enclosure of the generator and the lamp is no longer gastight, the air pressure is lost and the turbine stops, de-energizing the electrical system. This system is principally used to provide portable lighting but can, of course, also be used for fixed lighting.

Another popular way to provide safe lighting for dangerous spaces, such as pump rooms, is to light those compartments from a safe space by the use of glazed ports. When this method is applied it should be ensured that the integrity of the bulkheads is not impaired by the glazed port in respect of fireproofness or structural strength.

Time and again it is experienced that people do not quite know the difference between flameproof and intrinsically safe equipment. Flameproof equipment is normal equiment but provided with a flameproof enclosure. The definition of a flameproof enclosure is mentioned in M 109. This means that in principle every piece of equipment can be made flameproof such as lighting fittings, motors, switchboards, etc. On the other hand intrinsically safe equipment is a special apparatus wired in a special circuit, but provided with a normal enclosure. A definition for intrinsically safe apparatus is also given in M 109 and may be summarised as follows: Any fault that can happen in an intrinsically safe appartus (short-circuit, broken connections, etc.) is incapable of causing a spark with sufficient energy to ignite the dangerous gas or vapour. Consequently, the power available in intrinsically safe circuits is very limited and therefore only low energy circuits such as for measuring, monitoring, telephone, etc., can be made intrinsically safe. The subject of intrinsically safe circuits is extensively dealt with in the Instructions to Surveyors.

## 10. VARIOUS INSTALLATIONS

### (a) Steering gear installations

Some years ago almost all ships had a hydraulic telemotor system for the control of the steering system from the wheelhouse. As long as this telemotor system could operate and one of the steering gear motors down at the steering gear flat was running, steering from the bridge was possible. Nowadays many ships have no hydraulic telemotor system, but instead only electric control of the steering system which can be operated by the auto pilot system or by the helmsman. If this electric control system is defective, steering from the bridge is impossible even when both steering gear motors are running. To prevent this M 506 (e) requires that where electric control of the steering system is fitted an alternative control system is to be installed. This may be a duplicate electrical control system or control by other means. When no hydraulic telemotor or a similar system is fitted this means that two electrical control systems have to be fitted. However, in order that these two electrical control systems offer effective stand-by facilities it

is necessary to ensure that those systems are independent, have separate supplies and are so arranged that a fault in one can never render the second system inoperative. Systems have been proposed where one fault in an auto pilot circuit could interrupt the complete steering control from the bridge.

(b) **Navigation lights**

M 505 requires that each navigation light is to be provided with an automatic indicator giving audible and/or visual indication of failure of the light. When a visual indication alone is fitted this should preferably be arranged so that the indication lights burn when the navigation lights burn. It is sometimes proposed to have dark indication lights when all navigation lights are healthy, but this system would give no warning if at the moment that a navigation light circuit has a failure the subject indication light should have a broken bulb or another fault. There are automatic indicators which measure the current in the navigation light circuit and give an alarm when this current is interrupted. Some of these systems operate with electronic devices. Care should be taken to ensure that such systems are not too sensitive. Navigation lamps are usually mounted at unfavourable locations and the ingress of water and salt could well happen. This could result in leakage currents in the fitting or connection box. When an automatic indicator system is very sensitive it could happen that also when the lamp filament is broken the indicator measures a healthy circuit due to those leakage currents. The system should, therefore, be so designed that an alarm is given when the current is below a substantial percentage of the normal circuit current.

(c) **Socket outlets for refrigerated containers**

The location and supply of socket outlets for containers often presents problems. These problems are new and more experience has to be obtained before some definite ruling can be made. However, the following observations could be considered: —

(i) The sockets should be so constructed that the plug cannot be inserted or withdrawn when the system is energized. This means that a locked switch has to be incorporated in the socket.

(ii) The sockets should, preferably, not be placed on open deck. If this cannot be avoided it is suggested to install the socket inside a box with one side partly open to serve as entrance for the plug. Such a box gives additional protection against mechanical damage, water, etc.

(iii) As a classed refrigerated container is an essential consumer it could be considered that M 502 applies and consequently a separate final sub-circuit should be provided for each container socket outlet. When this is impracticable use could be made of socket outlets with built-in fuses. This requires, however, that the socket outlets are placed at positions where it is possible for the crew to renew fuses, and to be able to do so when the ship is at sea. It also requires that the supply cable is capable of carrying the combined load of the socket outlets connected to the subject circuit. This practice will be limited by the capacity of the terminals of the socket outlets to receive heavy supply cables.

(iv) The distribution boxes used to supply the container's sockets should be located at suitable places such as deckhouses, etc. Such distribution boxes should not be located on open decks or in cargo holds.

## 11. NEW CONSTRUCTION, PERIODICAL AND DAMAGE SURVEYS

These subjects are described in detail in the Instructions to Surveyors and in the paper written by Mr. Morris. However, the following additional remarks may also be useful.

(a) **New Construction Surveys**

In Holland and Belgium most electrical installations are designed and built by a few, rather large and competent, contractors. This favourable situation makes it easy to discuss in an early stage the new installations, i.e. before the actual work in the factory or on board is commenced. This is very attractive because it is to the benefit of all parties concerned that mistakes and faults are discovered well before the work is started and that agreement is reached on the important items, such as system design, plans, switchboard arrangements, materials, etc. Such early discussions with the builders make it sometimes possible to improve designs, e.g. in view of experience obtained on other ships, because at that stage most firms are quite willing to accept proposals, whether or not supported by Rules or Regulations. When installations have been fitted, no builder can afford to change them unless strictly required by the Rules or the applicable specification.

It is also worth while to inspect and test equipment in the factory before it is installed on board. Testing facilities are much better in a factory than on board and it is also much easier to make good or replace faulty items or to change constructions when found necessary. This certainly applies to main and emergency switchboards, but also to group starter boards, engineroom or bridge consoles, section boards, etc. In the Author's opinion it is reasonable that for such inspection work certificates are issued and fees are charged.

A substantial part of a New Construction Survey is spent on checking workmanship and materials during the installation of the electrical equipment. From the moment the first cables are laid, regular visits will be necessary to check cable work, location of equipment, installed materials, earthings, cable terminations, bulkhead and deck penetrations, etc.

The final part of the First Entry Survey is occupied by attending tests on the equipment. Generator and switchboard tests and megger tests are extensively dealt with in the Instructions to Surveyors. Of course, generator and switchboard tests should not only be carried out on main generators, but also on the emergency generator, when fitted. With a.c. installations it is advisable to test also the starting of the largest motor on a minimum number of generators running in parallel, in order to check whether M 423 is complied with M 423 does not specify the maximum allowable voltage drop; the general practice is that the maximum voltage drop under those circumstances should not exceed 15 per cent. Tests on the following installations will generally also have to be witnessed: emergency lighting, including a discharge test on emergency batteries during the prescribed number of hours; emergency stops for fuel pumps, ventilation, etc.; general alarm; $CO_2$ alarm; navigation lights, steering gear including the control system from bridge to steering gear flat; essential motors, etc.

With regard to motors, it may be emphasized that the settings of the overload protection relays are to be checked. It is very often found that these are incorrectly adjusted, mostly due to differences between motor currents originally shown on plans and the actual values found on the motor rating plates. In case the switchboard and generator tests have been

carried out with a resistance load (power factor 1·0) it is necessary to check the voltage regulation and the load sharing in a later stage, e.g. during sea trials, with the ship's load. The sea trials also offer a good opportunity to check the ship's load under normal conditions and to verify that sufficient consumers have been connected to the preference tripping system.

It is a good practice during the sea trials to run all generators and essential motors for a certain period, e.g. lubricating oil pump 1 during the first day and pump 2 during the second day of a two-days trial trip. It can finally be checked during sea trials that there are no excessive vibrations on equipment such as motors, panels, lighting fittings, etc., that machine bearing temperatures are normal, and that the load currents of motors are not in excess of the rated current.

Since UMS Notations are becoming more and more popular a lot of testing on control engineering equipment will also have to be witnessed, but it is considered that this subject falls outside the scope of this paper.

(b) **Periodical Surveys**

A few remarks concerning this subject may be made in addition to the information available in the aforementioned publications.

In view of megger test results and visual examination it is often necessary to clean electrical machines. When this is locally done, i.e. on board, it is often found that various sorts of "Electro Safety Solvents" are used to get the dirt out of the machines. Although they are called "Safety Solvents" none of these will be completely inert towards insulating materials and impregnating varnish. When the cleaning operation is finished the solvent should be removed from the machine and subsequently the machine should be properly dried. Finally, it is advised to provide the windings with a new layer of insulating varnish.

A far better way to overhaul machines is to transport them to a repair shop. The machines can there be cleaned completely, not only the parts which are within reach ; coils can be dismantled, commutators when necessary, etc. Finally, after cleaning, the machines can be re-impregnated. When this method is followed the machine will be in good order again for quite a few years, whilst when the machine is cleaned on board there is a good chance that the operation has to be repeated in one or two years in view of low insulation resistance.

Particularly on older ships it is often worth while to check the condition of lighting fittings in accommodation spaces. In many cases it will be found that the wiring of the fittings and the ends of the connecting cables are in very poor condition due to the heat from the lamp. Some accommodation space fires were caused by poor condition of such wiring.

With regard to testing of switchboards and generators at periodical surveys it cannot be emphasized too strongly that short-circuit protection devices of generator circuits should be properly tested or it should be otherwise ascertained that they are in good working condition. The short-circuit protection of generator circuits has a similar function for the electrical installation (and thus for the safety of the ship) as a safety valve for a boiler. Short-circuit and overload protection devices of generator circuits can be tested in one of the following ways: —

(a) **d.c. Installations**

(i) Reduce the setting of the relay to a minimum setting and apply load to the generator until the current taken is above the minimum setting of the overload trip. Check proper working and where possible compare the measured tripping time with the required time-current characteristics. (*See also* Instructions to Surveyors.)

(ii) If method (i) gives no result because the minimum setting is still too high, it should be ensured by hand that the protection relay is in good working condition and that the current setting is good for the particular machine. It should be noted that in this way the protection relay is not really tested.

(iii) Take circuit breaker(s) together with the protection relays from the ship to a well-equipped workshop, where the short-circuit trips can be tested. In most larger ports, particularly in districts where new building yards are also situated, workshops with adequate testing facilities will be present.

(iv) Separate the generator and its circuit-breaker from the remaining system, e.g. via built-in isolating links or by disconnecting busbar sections and make a short-circuit behind the generator breaker. Disconnect the equaliser connection for the subject generator and its compound field where necessary. Start engine and run generator at reduced excitation. The voltage will be very low and the breaker can be closed. The short-circuit current now arising can be regulated by the shunt regulator. This is rather a complicated method and should never be carried out without an engineer with sufficient knowledge of d.c. machines being present.

(b) **a.c. Installations**

(i) As (i) above for d.c. machines.

(ii) Use current injection transformer set. These are transformers with low voltage, high current secondary windings. The primary winding is connected to the main via a variable voltage transformer (variac) and the secondary winding is short-circuited or over the protection relay to be tested. The short-circuit current can be adjusted by means of the variac supplying the primary windings. Such transformers are portable and some can deliver currents up to 8000 amps. Again, in most ports injection transformers will be available.

(iii) Generator circuits provided with indirect operating protective devices, i.e. operating via current transformers, can be tested most easily. Assume the generator full load current is 1000 amps and the short-circuit relay setting is 3000 amps. Most systems will use in such case current transformers with rating 1000/5. Consequently the protective unit will operate if the current transformer delivers 15 amperes

$$\left(\frac{3000}{1000} \times 5\right)$$

Therefore, to test the protective relay it is only necessary to disconnect the current transformer and to inject a current of 15 amps into the protective relay. This can be done by means of a small current injection transformer and a variac. The size and weight of the units necessary for this test are negligible compared with those needed for the method mentioned under (ii).

(iv) The current protections of a.c. generators can also be tested by means of reactive current. With this method two alternators are operated in parallel and the excitation of one either reduced or removed, causing it to draw

wattless current, which can be used to test the current relays. In fact, with this method the kVA load sharing is deliberately upset in order to get high wattless load currents, causing no overload on the prime movers but of sufficient value to operate relays. The same result can be obtained when the excitation equalising connections, present in systems employing compounded self-regulated alternators, are interrupted.

(v) Similarly as explained for d.c. generators under (iv), protective devices from alternators can be tested by running the machine in short-circuit at reduced excitation.

(vi) As (iii) above for d.c. machines, i.e. in a well-equipped workshop on shore.

(c) **Damage Surveys**

Such surveys concern mostly cases when the vessel and/or her equipment was damaged by fire or water. In case of water damage it is important to know whether it concerned sea or fresh water and whether the equipment was flooded for a short or long time. For instance varnished-cambric lead cable, at least when the cable ends were properly finished, may be able to withstand flooding for one day; in that case the repairs can often be limited to an inspection, megger test (where necessary also between the various conductors of one cable) and new sealing and finishing of the ends. If, however, the flooding lasted for a week, complete renewal of the cable will in most cases be absolutely necessary. Similar conclusions can be made concerning machines, transformers, voltage coils of breakers and contactors, etc. Water damage of short duration can often be repaired by washing the equipment in clean fresh water, drying and re-impregnating. After a flooding of longer duration rewinding will be required.

In any case equipment damaged by water should be repaired on shore. All pumps, switchboards, machines, etc., must be completely dismantled, dried and inspected. Delicate equipment like relays, voltage regulators, meters, protective relays, accessories from breakers and contactors like small springs, washers, etc., can best be renewed. Also insulated supports, busbar supports, etc., are mostly to be renewed except when the subject materials are absolutely non-hygroscopic like porcelain, some forms of melamine, etc. When fire extinguishing media other than water have been used, it should be checked whether they are harmful to electrical equipment.

Of course, $CO_2$ is quite inert and will not lead to damage of electrical equipment.

Some extinguishing powders, however, can be harmful to electrical equipment, particularly in conjunction with water. It is therefore important that such extinguishers are removed from electrical equipment as soon as possible.

It will often be proposed to renew cables, not completely, but only that part affected by the fire or other damage. Where a substantial proportion of the cable is still healthy, this could be accepted provided the joints are properly made. It must be remembered that junction boxes will not so regularly be inspected as machines and switchboards. In fact, it is most likely that a cable joint box, particularly when located at a difficult position, e.g. behind ceilings or panelling, will never be opened up after being made. This means that the connections should be very good to avoid contact resistances arising with subsequent overheating and the danger of a new fire.

It is, therefore, the Author's opinion that bolted or screwed connections should be avoided in such joint boxes and that instead patent compression type joints should be made as manufactured by AMP and Burndy.

Further points worth mentioning are: The junction box should be sufficiently large to avoid the possible danger of faults between cable conductors or to earth, the connections should not be subjected to any mechanical load, the connections should be suitably insulated, the connections should be properly marked, and earthing of cables should be continued.

If the junction box is located at a humid location it can be advantageous to fill the junction box with a suitable electrical compound.

## 12. FACTORY TESTS

(a) **Switchboards, starter boards, section boards and similar panels or cubicles**

When inspecting and witnessing tests on switchboards, the following points may be considered:—

(i) Visual inspection of materials, general construction, creepage and clearance distances, wiring and connection, labelling and many other points mentioned in earlier parts of this paper, particularly part 4.

(ii) *Functional tests*

As far as possible operation of circuit breakers, switches, meters, synchronizing circuits, interlock systems, motor starter circuits, etc., should be tested. This applies also to protective relays, such as overload, short-circuit, reverse power, preference tripping, no-volt coils and similar systems. In this respect it may be useful to check that the settings of the protective devices conform to those mentioned on plans and discrimination diagrams. It is advisable to have the functional tests not only carried out at rated voltage but also at reduced voltage. It is the Author's practice when possible to carry out all functional tests at 100 per cent and 80 per cent supply voltage. The 80 per cent supply voltage is lower than the values mentioned in M 105; however, the values of M 105 are applicable for coils at their final operating temperature. The functional tests carried out in the factory are usually of short duration and the coil temperature and consequently the coil resistance, will be lower than when at final operating temperature. It is regularly found that equipment such as contactors, relays, etc., fail to operate at 80 per cent supply voltage. In most of such cases this is not due to the actual design of the equipment but to external reasons such as dirt, maladjustments or other factory faults. When such faults are remedied there is a better chance that the equipment will operate satisfactorily under normal conditions on board. Of course, when the design is such that the equipment cannot operate at 80 per cent supply voltage, even when, in optimal condition, the tests are repeated at the values given in M 105, however, at full operating temperature.

(iii) *High voltage test*

A test of 2000 volts during one minute has to be carried out on all switchboards (M 620) and should be applied between all current-carrying parts connected together and earth and between current-carrying parts of opposite polarity or phase.

For 3-phase a.c. switchboards the following method may

be applied to carry out the high voltage test in a quick and easy way:—

1. Connect phase R to S. Connect phase T to earth and remove all control current circuit fuses supplied from phase T.
   Apply test voltage between (R+S) and T. In this way the phases R and S are both tested to earth and to phase T.
2. Connect phase R to T. Connect phase S to earth and remove all control current circuit fuses supplied from phase S.
   Apply test voltage between (R+T) and S.
   Now the phases R and T are tested to earth and to phase S.

Consequently, in this way all phases are tested to earth and all phases to one another. Moreover, the control current circuits are also tested to earth, except the circuits supplied via control current transformers.

(iv) *Insulation resistance test*

This test must be carried out as mentioned under (iii), i.e. to earth and between all phases. It is important to check that during the high voltage and megger tests all circuits are connected, i.e. all switches and fuses are switched on, except as mentioned under (iii).

Although the above inspection and testing procedures are primarily intended for power switchboards, they may also be applied when inspecting control panels such as engine room consoles, bridge consoles, boiler control panels, etc., or so far as applicable.

(b) **Electrical machines**

As the subject of testing electrical machines is extensively dealt with in the aforementioned documents, only a few remarks will be made here.

Full tests, including temperature rise tests, are to be carried out on all machines, except in case of duplicate machines up to 50 kW, kVA or b.h.p. per 1000 r.p.m. as mentioned in M 427. When in the past most marine generators and motors had only limited capacity and were of d.c. construction, these requirements were perhaps justified. However, at present, with only simple a.c. machines, it may be doubted whether this ruling is still relevant. Also for larger machines it is the Author's opinion that a temperature test is a type test, to be carried out on one machine of a certain type and rating and manufactured with the same materials and manufacturing methods. In that case the following tests should be carried out on each machine:—

No-load running test.

Voltage regulating test (on generators).

High voltage test.

Insulation resistance test.

In addition to these tests the following tests should be carried out on one machine from a series of identical machines:

Heat run test at rated load or equivalent conditions.

Overload test.

Whether machines are identical in design and construction can be checked by comparing cold resistance values of windings and results of no-load running tests.

It is advisable that an overspeed test is carried out on all generators. Such overspeed tests are mostly carried out at 120 per cent rated speed during two minutes. In this respect it may be noted that Notice No. 3 to the 1970 Rules contains requirements for the provision of overspeed protection for auxiliary engines developing 300 b.h.p. and over. This requirement will only be effective when it is ensured that the generator can withstand speeds up to the maximum allowed setting of the overspeed protective device.

It is advisable that a locked rotor test is carried out on squirrel-cage induction motors. This test may check whether normal or excessive starting currents can be expected and may further give information concerning the available starting torque.

As already explained in this paper, it may also be advisable to carry out short-circuit tests on a.c. generators, i.e. on at least one machine of each type and rating. A short-circuit test proves the quality of the design and construction of a machine and, in addition, gives valuable information concerning short-circuit currents to be expected.

It may finally be noted that testing of machines is important but visual inspection of machines and examination during construction is perhaps more worthwhile.

Troubles in electrical machines are often caused by loose connections, poor welding, defective materials, bad workmanship, etc. Usually such defects will not be revealed during the final running tests but will appear after some time on board.

## 13. CONCLUSION

The foregoing remarks concern mainly power installations as now found on board ship and so far as they are interesting from a classification point of view.

No reference has been made to electric and electronic equipment now usually installed and serving essential equipment such as bridge control of propulsion, boiler control, alarm installations, dataloggers, instrumentation systems, automatic diesel and generator control, automatic cargo refrigerating equipment and steering gear control. In this respect it may be noted that electronic computers have already been installed on some ships.

It may further be expected that many future ships (large container ships, passenger ships, barge carrirers, L.P.G. carriers and similar ships with large electric power consumption) will be equipped with high voltage power equipment. But even when these new and complicated installations are not considered, it will be clear that the modern ship's electrical installations are no longer simple and straightforward.

It is further shown in this paper that ships' installations are only partly determined by Rules and information shown on approved plans. Choice of materials, workmanship and installation and testing methods are necessarily a matter of local decision.

Consequently, the amount and complexity of electrical survey work on board ship being classed with our Society is growing considerably.

There are no technical reasons which demand that all electrical survey work should be carried out by Electrical Engineer Surveyors. Indeed, this would be prevented by economic reasons. On the other hand, is it not to be expected that the average Engineer Surveyor should be capable to deal with all electrical survey work now presented. It is, therefore, the Author's opinion that good team work between the Engineer and Electrical Engineer Surveyor is the best method for this task, both from a technical as well as an economical point of view. In such a team the Electrical Engineer Surveyor would be primarily responsible for general points like

materials, system design, installation and testing methods, manufacturing of machines, switchboards, cables, etc. The Engineer Surveyors of such a team could be responsible for workmanship, testing of various installations on board and in factories, periodical surveys, etc.

There are districts in which such a scheme is already in operation and, as far as can be ascertained, works to the full satisfaction of all parties concerned. Teamwork, as suggested above, would also be very useful when surveys for UMS equipment and installations have to be carried out.

The statements in this paper express the Author's personal opinions and where these should be rectified or supplemented it is hoped that this will be done in the forthcoming discussion.

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# Discussion

on

Ir. W. de Jong's Paper

# SHIPS' ELECTRICAL INSTALLATIONS AND THEIR SURVEYS

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# Discussion on Ir. W. de Jong's Paper

# SHIPS' ELECTRICAL INSTALLATIONS AND THEIR SURVEYS

## AUTHOR'S GENERAL STATEMENT

The Author is indebted to all those who have taken part in the discussion as well as to those who have made written contributions.

The diversity of the comments made and questions asked contain useful information, based on experience gathered from all parts of the world. As such the comments make a valuable supplement to the paper.

It is hoped that the Author's replies will also make a suitable contribution.

## MR. D. GRAY (H.Q.)

Mr. Chairman, Ir. de Jong and Gentlemen. Some months ago I was asked by the Committee of the Staff Association to give my views on the future of the Association.

Among my proposals was the view that papers should be written by selected specialists, dealing with their specialist discipline but written for the non-specialist. In my proposals I put forward the view that such papers must be written in clear and concise language, readily intelligible to the non-specialist but nevertheless putting across the basic principles of the specialist discipline.

Here we have just such a paper, written for the non-specialist electrical engineer. What is even more important and commendable—it is written in English by a Surveyor for whom English language is a foreign language. I am sure that everyone in the audience and in the whole Staff Association will support me when I express not only congratulations but grateful thanks to you Willem de Jong for this paper.

It is a formidable and excellent paper. Formidable because of the breadth of its coverage and excellent not only for the quality of the language but for the mass of good information contained in it. I am sure that many non-professional electrical engineers will turn to it for reference in years to come.

It is not my intention to say very much on the details of the paper. I think it would be better if I left that to my colleagues—both specialist and non-specialist—who will wish to contribute to this discussion later both in person and, no doubt, for those who cannot be present tonight, in writing.

However, in the early part of the paper the Author has mentioned the effect of the marine ambient conditions, and the production by the Society of Lists of Type Tested Equipment. Some Surveyors may wonder why such lists should be necessary when the Society has functioned for so many years without such lists. It is true to say that, up to very recent times, electrical equipment for marine use was more robust than that for use ashore. It was "special" and, of course, carried an appropriate price tag as compared with its counterpart for use ashore. However, as all Surveyors are well aware the pattern of manufacturing is changing. Mergers and take-overs are the order of the day, so that whereas formerly there was a multiplicity of manufacturers many of whom would be prepared to design and manufacture special marine equipment, today we have one, or at the most, two large manufacturing units per country. These large units are engaged in cut-throat international competition. In order to get costs down each large manufacturer requires a long production line. Marine orders are very few compared with industrial orders. Consequently a production line for special marine equipment is almost impossible to set up. This means that there is more and more pressure on the part of designers and manufacturers to persuade the marine industry to accept "normal" or "standard" electrical equipment, i.e. industrial equipment. Indeed in the next five years we may see a position where the manufacturers will refuse to manufacture special marine equipment no matter what the price. At the same time the smaller firms, many of whom were specialists in marine equipment have either been taken over or driven out of business.

The special marine equipment was suitable for the marine environment—as shown by its satisfactory performance. The performance of industrial equipment in the marine environment is not fully known. The purpose of Lists of Type Tested Equipment is to list those equipments which have been tested against the marine environment. Such lists will not guarantee complete absence of failures, since correct application is as important as good design. The list will, however, sort out the obviously unsatisfactory at the design stage. This should help with correct application.

The Author has written at length on short-circuit currents and their importance on the design of the electrical system. This cannot be stressed too strongly. He has also mentioned the desirability of carrying out short-circuit tests on generators as a type test. This is agreed whole-heartedly but, in my view, to test the generator alone is not enough. It is the complete generating set, i.e. prime mover and generator, which should be type tested. After all, on board the ship in service, if a major fault occurs it is the generating set which must withstand the effects of the short-circuit. Yet in this problem the electrical engineer is in difficulty. Electrical machine designers and manufacturers would agree to the carrying out of such tests without too much demur. The diesel designers and manufacturers and the turbine designers and manufacturers are very reluctant to carry out such tests. Even within our own organisation, mechanical engineers recoil from such a suggestion. At the same time these designers of prime movers are sharpening their economic pencils just as much as the designers of electrical equipment. The time has come when they should be asked to prove by test that their equipment will withstand the effects of a contingency which may arise in service.

The Author has given a great deal of information on cable types and cable installation. In the old days with lead sheathed cable or with armoured cable, beautifully straight cable runs were possible. Indeed, in this respect a counsel of perfection was probably preached in many shipyards and splendid symmetry resulted. With the newer types of cable, the cable is more flexible. It is no longer always practicable to produce straight runs of cable with the cable taut between clips. At the same time the increase in the very number of cables has produced the necessity for greater bunching. Surveyors must realise that beautiful symmetry in cable installation may not be practicable with these newer types of cables, as it was with older types of cable, and furthermore symmetry is not necessary electrically. Lack of symmetry is not evidence of poor work-

manship. The cable must be firmly secured—after that it will carry the current and that is what it is supposed to do.

I have said quite enough. Thank you once more, Ir. de Jong, for this excellent paper. Now I will hand you over to the younger men whom I have no doubt have sharpened their knives to take you to task on some of the details.

### Reply to Mr. Gray

The Author is glad to note that Mr. Gray supports his view concerning the desirability of carrying out short-circuit tests on generators as a type test. It should be a standard practice for a generator manufacturer to carry out this test on one generator of each type and rating in order that the following may be assessed:—

(a) The capacity of a generator and its voltage regulation equipment to withstand short-circuits.

(b) The magnitude of the generator short-circuit current.

However, it is rightly pointed out by Mr. Gray that this is not enough. It is, indeed, the complete generating set, i.e. prime mover and generator, which should be type tested. However, this is not easy to arrange for the following reasons:—

(a) The manufacturers of the prime mover are reluctant because they can often insufficiently estimate the possible effect of the proposed testing.
In this respect it may be noted that there seems no reason for the prime mover manufacturers to be unduly worried about the possible damage to their machines caused by a short-circuit fault in the generator circuit.
The Author has heard of quite a few major short-circuit faults and in no case was it reported that the prime movers had also sustained damage.

(b) It is not easy to organize such testing because it requires the availability of the complete set, in operating conditions, and of sufficient testing equipment.

If it is felt that the time has come that it should be proven by real tests that the generating equipment, including its prime mover, is capable to deal with possible short-circuit faults, it would be best to have such tests carried out on board.

The short-circuit fault could be introduced behind the biggest main switchboard outgoing circuit whilst the system is supplied by the number of generators required to run in parallel under normal load conditions. Such testing would verify the following:—

1. Short-circuit capacity of the generator sets.
2. Short-circuit capacity of main switchboard busbar system.
3. Discrimination of the protective devices of generator circuits and biggest main switchboard group(s).
4. When, during this test, the short-circuit currents are measured, also the short-circuit calculations can be checked.

In the Author's district such tests have been carried out on a few ships and this experience shows that it is not complicated or time consuming to carry out such tests. The most expensive and complicated part of it is the installation and operation of the current measuring equipment, i.e. the oscillograph and its ancillary equipment. However, although the measured values of currents are most interesting, it is not essential for this testing to measure the currents which occur at the introduced short-circuits.

As practice shows that major short-circuit faults do regularly occur, I do not think that prime mover manufacturers are on strong grounds to refuse such tests.

### Mr. A. C. Bailey (H.Q.)

To preserve continuity of supply is perhaps the most important requirement of any well-designed, completed system. Loss of an essential service could be fatal, for which reason the Rules require standby generating capacity, duplicate pump motors, preference tripping, etc.

There is generally, however, only one main switchboard. Its construction, therefore, must not be such as to remove, if possible, the chance of faults or at least to contain them.

Therefore, the Author's section dealing with switchboards is, in my view, extremely valuable.

At the same time the philosophy advocated, i.e. complete accessibility of components and connections, good and clean ventilation, represents an ideal rarely attainable and certainly not on small ships.

In fact, engine rooms are dirty and switchboards must often be made to small physical dimensions and be called upon to be the heart of the installation under adverse conditions.

In my view, therefore, important points are to divide a switchboard into cubicles, mount busbars in a segregated busbar chamber and to instal busbar isolating switches.

So, whilst attention to the details so clearly defined by the Author will reduce the possibility of faults, those which are inevitable can be contained and faulty sections taken out by means of the busbar isolators.

This, I am sure, is second nature to the Author; but too many boards, wrongly in my view, are still made on the old d.c. pattern, i.e. with no segregation and open busbars so that a fault initialiy minor, is allowed to develop into a major busbar fault with resultant loss of total power.

It is stating the obvious truth, but attendance at makers' works, in the design stage, is necessary if this philosophy is to be brought home. When completed and installed on board it is then too late to make objections.

### Reply to Mr. Bailey

It is fully agreed with Mr. Bailey that continuity of supply is perhaps the most important requirement of any well-designed ship's electrical system. It is, therefore, self-evident that the construction of the "one and only" main switchboard must be such as to restrict the chances of faults as much as possible. In this respect it may be argued that on a number of important and expensive ships now being built or planned it would be worthwhile to separate the electrical supply in two independent systems, both capable of supplying power to all essential services necessary for service at sea. This idea would be particularly worthwhile to be considered for ships with two propellers each driven by its own propulsion system. However, practically all ships now at sea or under construction have only one main switchboard and it is whole-heartedly agreed with Mr. Bailey that it is advisable to divide switchboards into cubicles, to mount busbars in a segregated busbar chamber and to install busbar isolating switches in order to disconnect faulty sections and to keep healthy sections alive.

The switchboards shown on Figs. 3 and 6 of my paper were built along this pattern.

It may further be noted that an attractive feature of switchboards made by A. de Hoop N.V. is their way to provide pertinax insulation around all main busbars. An example of this practice is shown in Fig. 1 of this discussion.

The risk of having major busbar faults is considerably reduced by this practice.

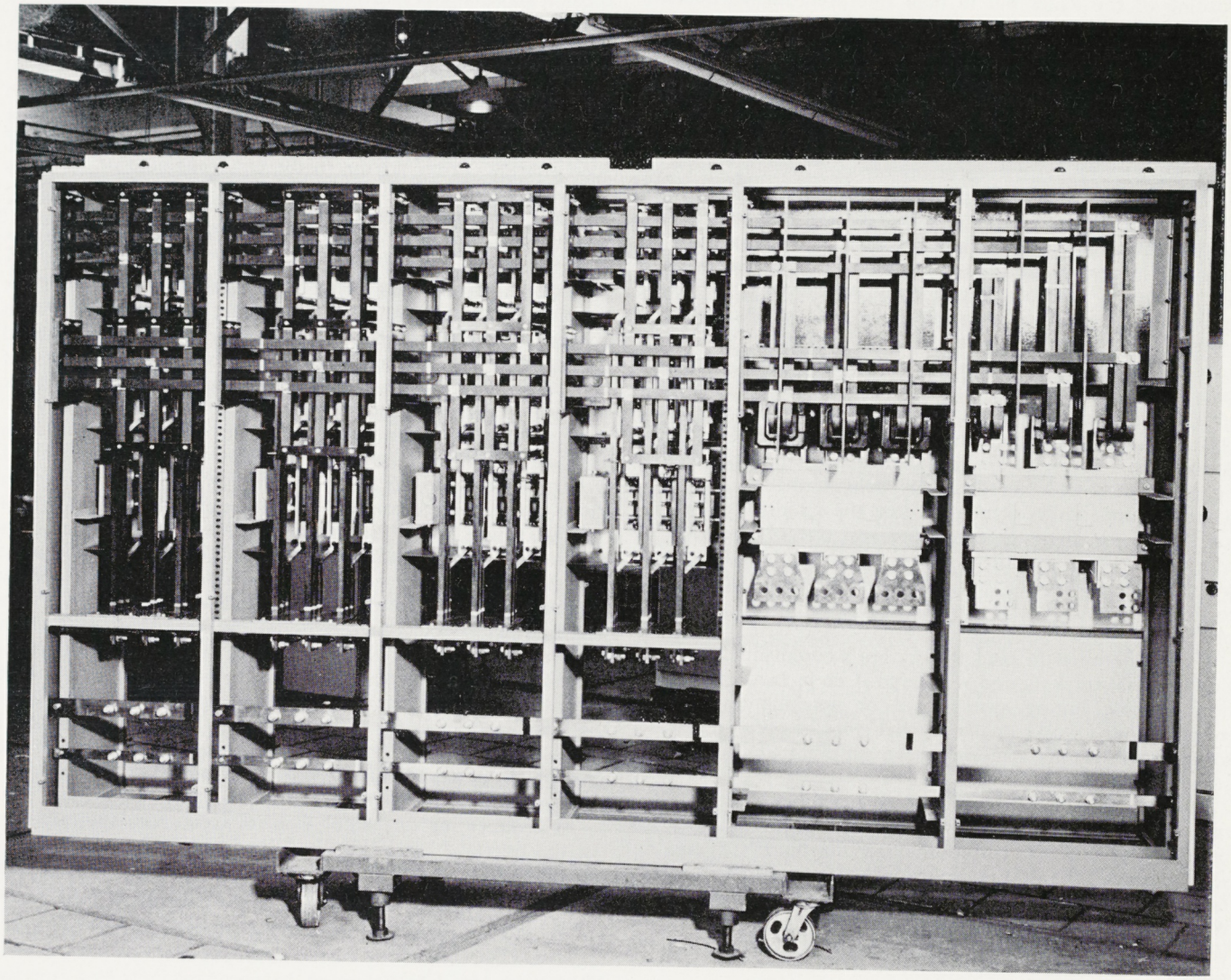

FIG. 1

MR. D. C. D. CLARK (Newcastle upon Tyne)

I should like to congratulate Mr. de Jong on the content of his paper which I found extremely interesting. As a young Surveyor I found it very difficult initially to decide on the standard of workmanship I would accept lacking both experience and confidence in the practical side of electrical engineering and am sure Mr. de Jong's paper will prove very useful in this respect. I should like to comment, however, that one of the main problems I have encountered is not in the actual wording of the Rules but in their interpretation particularly when faced with an elder experienced electrical foreman who continually insists that "the previous Surveyor never asked for that".

Mr. de Jong mentions ambient temperatures when discussing operating conditions on board ship and in particular the high temperature rise inside cubicles. We have at present in this port a turbo-electric drive under construction for which the generator excitation is provided by a thyristor regulator bank mounted in a cubicle. It is well known that the thermal capacity of these devices is low and the junction temperatures must not exceed a specified value even momentarily without risk of loss of control. Consequently the designed maximum ambient cooling medium temperature as well as the prospective current loading for these devices must be known and maintained accurately for economic operation. For this particular installation the thyristors are fan cooled and fitted with a generator field overcurrent alarm and automatic current limiting facilities on failure of the cooling fan. I wondered if the Author has had any working experience of thyristor devices on board ship and can offer any help in this respect. It is perhaps worth while to mention that the majority of generator AVR's are thyristor controlled and one of the ways by which the device junctions temperature can be exceeded is when the thyristors are turned fully on causing high currents to flow on loss of voltage by the generator during shut down of the set.

I was interested to read the Author's comments on insulating material tracking and wondered if he in fact tests insulation tracking during switchboard or machine tests at the manufacturer's works or if not what steps he takes in practice to ensure insulating materials have sufficient ability to withstand tracking.

I agree with the Author that for machines in service 0·1 megohm is a dangerously low insulation resistance and it has been my practice to ensure that all machines for essential services have at least 1 megohm insulation resistance. In this respect I do feel that it should be stressed that a megger test is not the full requirement of an electrical special survey and can only serve as a guide to the state of an electrical installation.

Referring to the Author's comments on installing electrical machinery below the engine room floor, one of the difficulties I have encountered is that the shipbuilder is not aware of the consequences of this practice, being more concerned with the position of the pump rather than the electric motor. For efficient operation, the height of a pump above its tank is critical and in larger ships this inevitably means the pump is mounted well below floor plate level. As far as the shipbuilder is concerned the pump and motor are one unit which he is reluctant to tamper with and having decided the position of the pump, the electric motor just has to fit in. As far as the pump manufacturer is concerned he is building standard units and anything to alter his standard immediately becomes a "special". Consequently, no one is prepared to extend the drive shaft that extra foot in order that the electric motor may be mounted in a position more favourable to its satisfactory and efficient operation.

Concerning switchboards and synchronisers I think more care could be taken in the design and mounting of such equipment. On one particular newbuilding in this area an automatic synchronising panel and control was mounted remote from the main switchboard controls. The equipment could only operate within set limits of generator voltage and frequency and the governor motor control was wired through the auto manual changeover switch on the synchroniser panel. Consequently the operator had to adjust the machines to within the voltage and frequency limits of the auto synchroniser, walk over to the auto synchroniser panel and switch to automatic, wait for the sets to synchronise, switch off, then return to the main switchboard, and adjust the kVA and kW load sharing. From talking to the chief engineer of the ship, I understand it is standard practice to switch the auto synchroniser off and lose the control keys!

Referring to hinged doors fitted with current carrying parts it has often been found that the wiring for these devices has been too tight and on opening the door, is pulled out of its terminations, often chafing on the cubicle frame. In addition to the Author's remarks I would suggest that such hinged panels be fitted with an open position locking bar, to prevent the panel closing onto the electrician as he carries out work inside a section whilst at sea.

The Author's comments on short-circuit calculations can only be agreed with, however, I think it should be added that generators built to BS 2613 are not required to be fitted with short-circuit maintenance C.T.'s as required by BS 2949 and I.E.C., which would seem to indicate the importance of investigating the compatibility of the generator short-circuit and the circuit-breaker operating characteristics. Consequently I would like to suggest these be investigated together with the short-circuit calculations required by M 102 at the Plan Approval stage. It is also interesting to note that theoretical estimation of a machines' subtransient reactance (and hence calculation of the short-circuit currents) is not particularly accurate, and again for machines built to BS 2949 and BS 2613 are subject to tolerances of $\pm 30$ per cent. Perhaps one of the best methods of estimating prospective short-circuit currents is as suggested by M 611.

In commenting on Motor Control Gear, the Author refers to the overload alarm required by M 506(a) of the Rules. I should be interested to know if it is the Dutch Surveyors' practice to interpret this alarm as an audible device or visual indication.

REPLY TO MR. CLARK

The cooling arrangements for the thyristors used in the excitation system of the generators of a turbo-electric propulsion installation explained in Mr. Clark's comments seem to be sound. When the thyristor fan cooling system has been provided with air filters it may be worthwhile to ensure that the cooling cannot become unduly ineffective due to the filters being choked by dirty air.

It might further be advisable to ascertain that the automatic field current reduction, which would operate on fan failure, could not endanger the vessel if this occurred during manœuvring. If this was the case it could be considered for initiating an alarm on fan failure and to cause current reduction before

the thyristors reach a predetermined high temperature. Of course, this can only be effected when it is possible to install temperature feelers sufficiently close to the thyristors.

I do not fully agree with Mr. Clark's remark that the majority of generator A.V.R's use thyristors. The Author is happy to report that at least on the Continent the simple and robust self-excited compound generators using a few reactor coils, transformers and diodes for excitation, are still very popular and, in the range up to 750 kVA, have the largest share of the market. Of course, the voltage regulation of such generators may not be ideal, but this is made good by simplicity and reliability. Moreover, experience on hundreds of ships has proven that the voltage regulation may be satisfactory for all practical purposes.

The "tracking" or better "anti-tracking" properties of insulating materials are not measured during switchboards or machine tests. These tracking tests are type tests and have to be carried out by the manufacturers of the components such as switches, terminals, etc.

When there is doubt whether an insulating material has sufficient ability to withstand tracking, one of the following methods can be followed depending on the situation: —

1. A material specification is requested.
   With such a specification it is often easy to determine whether the material is sufficiently tracking resistant. If it appears, e.g. that the material is melamine there is no further doubt about its tracking resistance.
2. Reports of tracking tests carried out by the manufacturer are requested and examined.
3. Tracking tests are witnessed at the manufacturers.

The Author fully agrees with Mr. Clark that a megger test is not the one and only requirement of an electrical special survey. The megger test report is a useful guide to check the state of an electrical installation, provided it is properly examined and low readings are taken care of. One gets, sometimes, the impression that the megger test report was immediately filed after being made.

In addition to the megger test and further testing required for a periodical survey, a visual examination is also a basic part of a survey. It should, further, be realised that a megger test only indicates the state of the insulation to earth and usually not between poles or phases.

As outlined in the paper the provision of short-circuit current maintenance is of prime importance when designing the excitation system for ship's alternators.

In view of various clauses of Section 6 of Chapter M of our Rules, such as those requiring proper protection against short-circuits and discrimination of protective devices, this should be considered as a Rule requirement. In view of Mr. Clark's remarks this could consequently mean that a generator made to BS 2613 needs not automatically to be in compliance with our Rules in this respect.

Overload alarms for steering gear circuits (although their value is doubted by the Author for common hydraulic steering gear systems powered by induction motors) should be so arranged that the occurrence of an alarm is quickly noticed by the crew. A visual alarm in the engine room is clearly insufficient for this purpose. When this alarm is installed in the wheelhouse, a visual alarm only, provided it is prominently displayed, might be sufficient.

MR. G. R. STYRING (Sydney)

Mr. W. de Jong is to be congratulated upon providing a valuable addition to the Associations' Transactions which is particularly welcome in view of the considerable developments in marine electrical practice since the presentation of the last paper on this subject. The Author should also be complimented upon finding and maintaining the fine balance between simplicity and sophistication so necessary when writing a paper intended for engineers having a different basic training from his own.

The Author appears on page 2 to be drawing a distinction between "Klippon" and similar terminals and mechanical clamps, but it is not clear how they differ. However, I agree that experience shows the need for special attention to mechanical clamps. It has been my practice with "Klippon" terminals to call for crimped spade ends on finely stranded flexible cables, allow terminals with flat clamping surfaces for cables having up to seven strands and terminals having dished or "V" shaped cross-section clamping surfaces for cables having more than seven strands.

Experience suggests that some of the troubles associated with terminal arrangements may be due to the non-availability during installation on the ship of suitable tools, e.g. box spanners, "Philips" screwdrivers, etc., and the use of inadequate substitutes. This is borne out by terminations made at the shipyard which compare most unfavourably with factory-made terminations of similar design on the same piece of equipment made perhaps up to two years earlier. Does the Author consider that this may be as important a factor as "setting" of the conductors?

The criterion of 1,5 mm. thickness for sheet steel panels given on page 3 appears to be rather arbitrary. In protected locations such as engine rooms and accommodation I have not found corrosion to be a problem and the use of a gauge of steel to give adequate mechanical stiffness appears to be a more important consideration. In locations such as forecastles and deck houses where corrosion may be expected it is doubted if 1,5 mm. steel panels would be adequate in all cases and the Author's comments would be of interest.

The comment, also on page 3, that the presence of dry dirt alone will not induce tracking is very interesting but I would have expected this to depend on the nature of the dirt and some amplification of this point would be appreciated.

The Author expresses doubts, on page 9, about the adequacy of manual synchronising arrangements and perhaps he could state the reasons for the doubts, as local experience, which includes a number of smaller ships on the Australian coast, indicates that mal-synchronisation is not a serious problem.

On page 21 there is a passing reference to low-frequency operated preference tripping systems and I would be glad to know if the Author considers that it is justified to accept such systems, as there is no safeguard against a system being set to operate at, say, 5 per cent above nominal frequency on full load with the risk of the preference tripping not being initiated until the prime movers are stalled.

With reference to the use of common control circuit transformers, raised on page 28, it is considered desirable that the starter isolators should have contacts provided to break the control circuit feeds, to safeguard personnel and no-volt protection. In addition, it should be ensured that no-volt protection is not sacrificed in the case of starters fed with power

from a non-essential section of the switchboard but deriving their control circuit supply from a transformer fed from the essential section of the switchboard. It is a common practice to arrange for preference trip and remote stop signals to be fed to the shunt-trip coils of moulded case circuit-breakers. In such cases it is considered desirable that an indication of availability of the tripping supply be provided and incorporated in the annunciator/alarm system if one is fitted.

Regarding the warning on page 33 of sharp edges on steel pipes, I would like to add that this can also be a problem on pipes made from some of the harder grades of PVC.

I would join the Author in stressing the need for ensuring the use of the right tools for fitting compression-type sockets having repeatedly found wire cutters, pliers or hammers used for this purpose.

### Reply to Mr. Styring

Interesting remarks are made by Mr. Styring regarding the use of "Klippon" and similar terminals. The use of crimped spade ends on finely stranded flexible conductors is an excellent and perhaps necessary precaution when using such connections.

Extreme care should be taken when accepting terminals with flat surfaces, also when used for conductors having seven strands or less. In the Author's opinion this is only permissible when the terminal is such that no strands can move in a direction parallel to the clamp surface, i.e. when the conductor is enclosed at all sides.

It may further be noted that "setting" of the strands is particularly possible with conductors having only a limited number of strands.

It is agreed with Mr. Styring that the use of the right tools is essential and that as such this may be as important a factor as "setting" of the conductors. Finally, the condition of an electrical installation is determined by workmanship.

Even the finest materials and techniques will fail when badly installed and connected.

Of course, the criterion of 1,5 mm. thickness for sheet steel panels is only a rough guide, used for general application and not for very unfavourable locations as semi-enclosed and unheated deckhouses and forecastles. However, the Author found at periodical surveys carried out on ships of, lets say, 12 to 20 years old that in quite a few cases corrosion is an important problem, also for sheet steel panels located in machinery spaces. Ventilation air on a ship is sea air and does, as such, contain salt and moisture. It is the Author's opinion that corrosion on a ship starts right at the beginning of the new-building period, never stops and can at most be delayed by correct maintenance. How adequately corrosion is delayed can be confirmed by all Surveyors regularly attending repair yards.

The Author also expected that the nature of the dirt would have an important influence on tracking. The life tests, however, showed that the presence of dry dirt alone did not start tracking. Perhaps the currents flowing between the poles or phases due to the presence of conductive dry dirt alone have insufficient thermal energy to attack the insulation material and to cause real tracking. But this is only an assumption.

With regards to the adequacy of manual synchronising arrangements, it may be explained that the Author's doubts were caused by unsatisfactory reports received from builders and repair yards which were called in to repair damages sustained by alleged mal-synchronisation.

It is also based on experience obtained during commissioning when it was observed that quite a few of the ship's engineers have difficulties in operating the synchronisation systems and circuit-breaker closing gear. However, the Author has to admit that on many ships satisfactory results have been obtained with manual synchronising.

The Author considers that low-frequency relays, used in conjunction with overcurrent relays, can make an ideal preference tripping system. As explained in the paper the power factor of the load makes it difficult to use current relays only, as with high power factors the prime movers will stall before the current relays can operate. A frequency relay, adjusted, e.g. at 95 per cent of rated frequency, will in such case operate the tripping system and ensure continuity of supply to the essential consumers and, perhaps more important, it will also safeguard continuity of supply if in due time, or due to high ambient temperatures the prime mover capacity is reduced from, e.g. 500 kW to 450 kW, making it more likely that the prime mover will stall before a current relay would have a chance to operate.

A frequency relay should, however, always be used in conjunction with an overcurrent relay because otherwise, in case of a low power factor, the generator could be overloaded without the preference tripping system coming into operation.

Mr. Styring's remarks concerning motor starters have been noted with interest and are supported. However, the Author does not favour the use of shunt-trip coils for preference trip and remote stop signals. In fact, it is the Author's opinion that this should be forbidden. Particularly for emergency stop systems this practice is dangerous because a local fire, damaging some remote stop cables, could prevent the operation of the emergency stops. Similarly, power failure would prevent the operation of such circuits. For preference trip systems this practice could result in non-operation of the preference tripping because often under conditions of a severe overload (*see* page 21 of the paper) the system voltage is reduced considerably.

### Mr. R. E. GIBSON (Sunderland)

I would like to congratulate Mr. de Jong on his paper which covers a wide field in a comprehensive and informative manner. I would like to comment on the following sections of the paper.

**Main Switchboard**

The Author has stressed the importance of protective measures against the ingress of water or other fluids in switchboards. I would like to add that as switchboard manufacturers are trying to reduce the costs of their switchboards there is an increasing tendency to build switchboards without back covers. This type of switchboard obviously creates problems when positioned in the vicinity of pipework and even though the switchboard may be protected so as to exclude water under normal circumstances, switchboard faults have occurred during fitting out and testing due to incomplete pipework or over-pressure.

When the space at the rear of switchboards is enclosed there is a tendency for the ship's staff to use the area as a store, thus increasing the possibility of fire or damage to the switchboard.

**Short-Circuit Protection**

The Author has quoted examples of main swithboard faults, I would like his comments on the incidence of generator faults and whether unit protection such as circulating current or Merz Price Protection is justified for generator circuits.

In the condition where two generators run in parallel, it would appear difficult for existing generator short-circuit protection to discriminate correctly when a short-circuit fault occurs at one generator. Unit protection would overcome this difficulty and in addition would offer the advantages of low fault setting and fast fault clearance.

When more than two generators run in parallel the use of instantaneous high setting overcurrent relays would surely create difficulties in choice of setting. The relay should be set low enough to operate for arcing faults at the generator and at the same time should not have a setting above the fault current that can be supplied when the minimum number of generators are operating in parallel. Unit protection, of the type mentioned above, would overcome this difficulty.

**Installation of Cables**

The Author has remarked on the installation of single core cables for a.c. circuits, from the point of view of minimising the effects of eddy currents in adjacent steelwork. I would be interested to hear his comments on the installation of two or more single-core cables per phase in 3-phase circuits and the possibility of different cable impedances causing unequal loading or overloading of the single-core cables.

**New Construction and Periodical Surveys**

The methods described for testing a.c. circuit-breaker overloads by current injection are, in my opinion, the best means of assessing the overload characteristics. However, the following points may be of interest.

When the overloads are current transformer operated, primary injection provides the best method as the operation of the current transformer is tested in addition to the overload. However, by virtue of the fact that the injection equipment should be capable of supplying large current it is inherently large and heavy.

Secondary injection, as the Author has stated, necessitates much lower levels of injection current and hence the equipment is easily portable. However, when using this equipment, it is thought unnecessary to disconnect the current transformer since, provided the injection voltage is low, only a small value of magnetising current would be supplied to the current transformer secondary winding. This method of injection would in some measure test the current transformer for shorted turns.

REPLY TO MR. GIBSON

It was noted with pleasure that Mr. Gibson amplified the Author's notes concerning the enclosures of switchboards and protective measures against the ingress of water or other fluids. It is the Author's firm opinion that it is a very bad practice to build switchboards without back covers. Perhaps this was a good practice in earlier days but it is now absolutely out of date. Besides the danger of ingress of water, there are many other arguments against open-type switchboards such as: reduced crews for maintenance and cleaning, very short stays in port for survey and overhaul, higher fault levels, use of equipment of much smaller size than in earlier days for the same rating, more compact switchboard building, etc.

For large generating sets, i.e. in excess of, say, 1,500 kVA, the Author would welcome the use of unit protection, because such protection could limit damage to an expensive generator. In other cases, however, it could be argued that the price and extra complication of a unit protection system are not worthwhile. It should be remembered that heavy short-circuit faults in generators are rather uncommon. It is agreed, however, that a well designed unit protection could prevent a black-out because with such system it would be rather easy to obtain discrimination in case a fault in a generator is supplied from the remaining generators.

Interesting information regarding the subject of unit protection can be found in Report NS.288 from the British Ship Research Association "Internal-Fault Protection of a.c. Marine Generators" written by Mr. J. A. Hall, B.Sc.

Mr. Gibson touches an important subject where he speaks of the installation of two or more, single-core cables per phase in three-phase circuits. With this practice it should be carefully checked that the impedances of the cables are about equal. In long cable runs this could mean that special installation measures are necessary to ensure that not only the lengths of the cables are equal but also their location in relation to the presence of steel cable trays, cover plates, bulkheads, etc.

MR. F. H. TICKELL (Newcastle upon Tyne)

The Author is to be congratulated upon the contents of his paper which will no doubt prove of value to his electrical and engineer colleagues.

Reference is made in the introduction to the paper to varied and numerous sources of information which will prove very useful, but it is suggested that the Surveyors should not lose sight of the fact that in the final analysis, it is the interpretation of the Society's requirements as laid down in Chapter M of the Rules, which are of cardinal importance.

Referring to Fig. 1 and tracking failures, it is my opinion that the makers of motors and alternators do not pay sufficient attention to the provision of flash barriers between phase connections in the terminal boxes of these machines, especially when the insulating material upon which the terminals are mounted is in the horizontal plane.

A case occurred recently during the commissioning of a new ship where a "short-circuit" took place in the terminal box of a 600 kW alternator due to the accumulation of dust (probably "welding flash") on the horizontal surface of the terminal insulation and due to the vibration of the running machine, the dust eventually lined up between phases resulting in the "short-circuit". It should be added that this dust accumulation took place towards the back of the terminal box and would not have been easily seen by the workmen engaged on the connection of the main cables, etc. However, had flash barriers been fitted in the terminal box, this fault would not have occurred.

With reference to the Author's observations on socket outlets located on the open deck of tankers, I would make the comment that as the Rules do not permit the use of flexible leads in hazardous areas, the installation of socket outlets in such areas are in consequence prohibited.

In the conclusion to the paper, the Author mentions the complexity of electrical survey work on board ship and he may be aware that it has been stated that the future policy of the Society is to recruit and train Surveyors to be capable of carrying out the necessary survey work both for hull and engine and presumably electrical, this being the case, would the Author comment upon the extent to which he thinks the services of so-called electrical specialists would still be required.

### Reply to Mr. Tickell

The Author agrees with Mr. Tickell's statement that the interpretation of the Society's requirements, as laid down in Chapter M of the Rules, is of cardinal importance. However, it is hoped that the sources of information referred to in the introduction of the paper could be of assistance when trying to find the correct interpretation of our Rules. It is further considered by the Author that our primary task is to ensure that ships get good and reliable electrical installations and our Rules are important tools to achieve this goal. However, general engineering knowledge, both theoretical and practical, is also indispensable in order to perform our task correctly. Perhaps the above mentioned sources of information could also be of value in this respect. It is interesting to note Mr. Tickell's remarks regarding terminals of motors and generators. It is agreed that the provision of flash barriers between phase connections is a good method to prevent faults in terminal boxes.

With regards to the final paragraph of Mr. Tickell's comments, it is the considered opinion of the Author that more than ever the Society requires the services of the so-called electrical specialists. Such specialists, however, should closely co-operate with the non-specialist, all-round Surveyors. Jobs which can be carried out by an all-round Surveyor should not be carried out by a specialist. Teamwork should be promoted for evident economical reasons. When this would be the future policy of the Society as indicated in Mr. Tickell's comments the Author would whole-heartedly agree to it.

## Mr. G. COGGON (H.Q.)

As a Ship Surveyor I have very little to contribute to this discussion but I would first of all like to compliment the Author on his paper. I am not competent to assess its quality but it certainly appears to be a very comprehensive work which will no doubt be greatly welcomed by the many mechanical engineer surveyors all over the world who, with limited expertise, in this field have to survey items of electrical equipment.

In Section 9 of the paper, dealing with the dangers of explosions from electrical installations on oil tankers, Mr. de Jong refers to M 1603 of the Rules and mentions two methods of illuminating the cargo pump room, the first an acceptable portable means, and the second a fixed means.

The fixed means is a permanent, approved, gastight lighting fitting, inserted in the bulkhead between the engine room and the cargo pump room. It is required to have adequate strength and be capable of maintaining the integrity of the bulkhead as an "A" Class division.

Such fittings are type approved. They are not accepted in aluminium because an aluminium fitting could not withstand the standard fire test required for "A" Class fire divisions.

These fittings, when properly fitted and kept closed, are no doubt efficient, but should the back plate in the engine room be left open we are left with only a piece of glass between two compartments which are both major fire hazards.

It is reported that at least one such light fitting was blown out by the explosion on the *Marpessa*.

One may, therefore, conclude that such fittings, whilst acceptable, are by no means foolproof.

Could the Author please tell us the approximate number of these fittings used in a cargo pump room bulkhead and give us an alternative fixed system of lighting which is acceptable under M 1608.

Also, since lighting from one side only cannot be considered very efficient, could he say why the bulkhead fittings are so popular as a means of illuminating pump rooms.

It is evident from the discussions at recent meetings of the Fire Safety Sub-Committee of IMCO that it will soon be mandatory to have fire subdivision of crew spaces in tankers, similar to that now required in passenger ships. It would, therefore, be of great advantage if the Author could let us know, perhaps in his written reply to the discussion, some approved methods of maintaining the integrity of A60 fire divisions in way of the penetration of electrical cables.

### Reply to Mr. Coggon

Mr. Coggon's comments prove that, after all, the building of a ship is a combined effort of a number of disciplines and not only the sum of the individual achievements from a few independent departments. As such, and evidently also for its technical contents, his contribution is very much welcomed by the Author.

Mr. Coggon's remarks regarding the bulkhead lighting fittings of tanker pump rooms are very interesting.

It was, indeed, the calamity of s.s. *Marpessa* which had given rise to the remark in Section 9 of the paper, having regard to the integrity of pump room bulkheads in which such light fittings have been mounted.

The number of such fittings used is, of course, dependent on the size of the pump room. On ships like the *Marpessa* about six to eight of such fittings will have been mounted. Such lighting fittings are used because they are considered to be more safe in view of explosion danger than explosion proof fittings located inside the pump room. They require no cables in the pump room and all connections are made in a safe space. Also lamp exchange can be done from a safe space.

An alternative method is the use of fixed flameproof lighting fittings located in the pump room. However, up to now only lighting fittings using incandescent lamps have been certified flameproof for this purpose and the amount of lighting produced by such fittings is limited. Bulkhead type fittings can make use of fluorescent lamps, sodium lamps and similar lamps giving a much higher light production. This is an additional reason that bulkhead type fittings are popular for large pump rooms.

It is interesting to learn from Mr. Coggon's comments that in the near future IMCO will require fire subdivision of crew spaces in tankers.

There are quite a few methods of maintaining the integrity of A60 fire divisions in way of the penetration of electrical cables. Fig. 2 shows a drawing of a so-called "Brattberg" cable bulkhead packing box. This system is quite popular in Holland and, when properly installed, it provides a gastight, watertight and fireproof cable penetration.

It consists of a ring welded in the bulkhead or deck through which the cables are inserted. Around the cables oil- and fire-resistant fibre (hard rubber) pieces are fitted and pressed together by a pressure plate. When the penetration is ready, i.e. has been tightened, care should be taken that all fibre pieces are well in position and that all metal clamps which have to be fitted between two layers of fibre pieces have indeed been fitted. Without these clamps the fibre pieces may get loose.

Fig. 3 shows a photograph of a "Verolme Elektra" gland, also providing a gastight, watertight and fireproof cable penetration. It consists also of a ring welded in the bulkhead

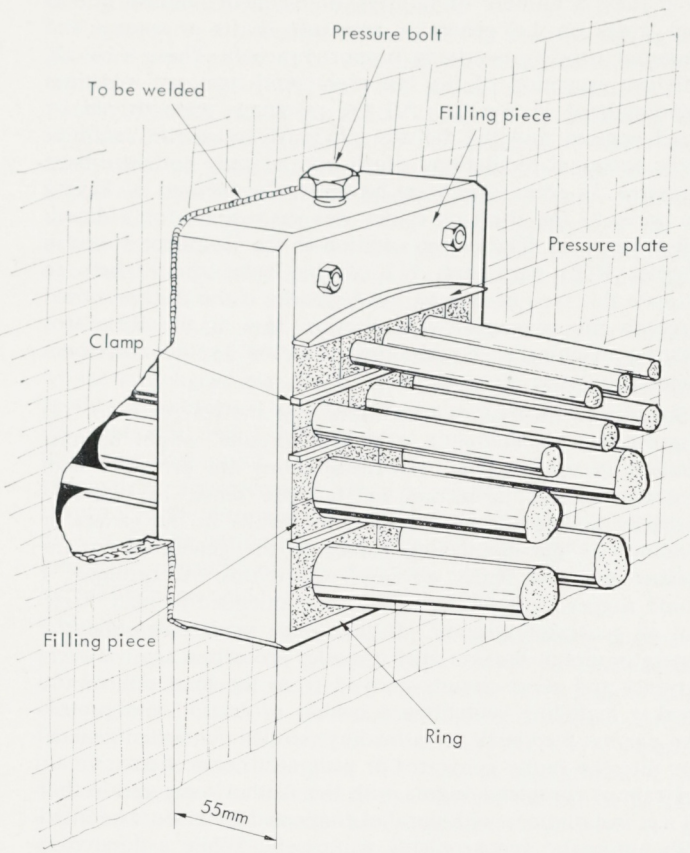


FIG. 2

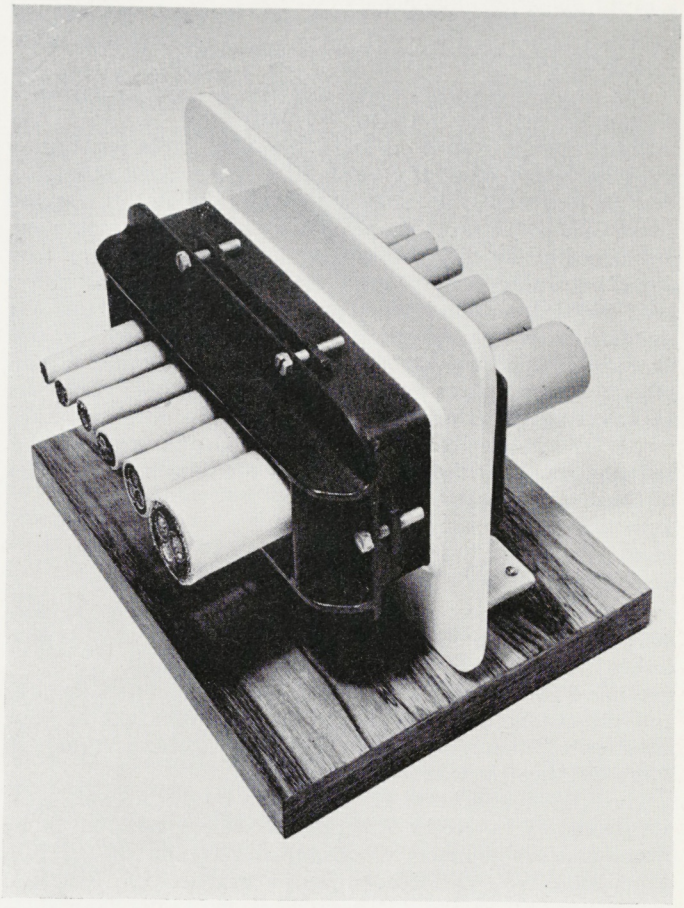

FIG. 3

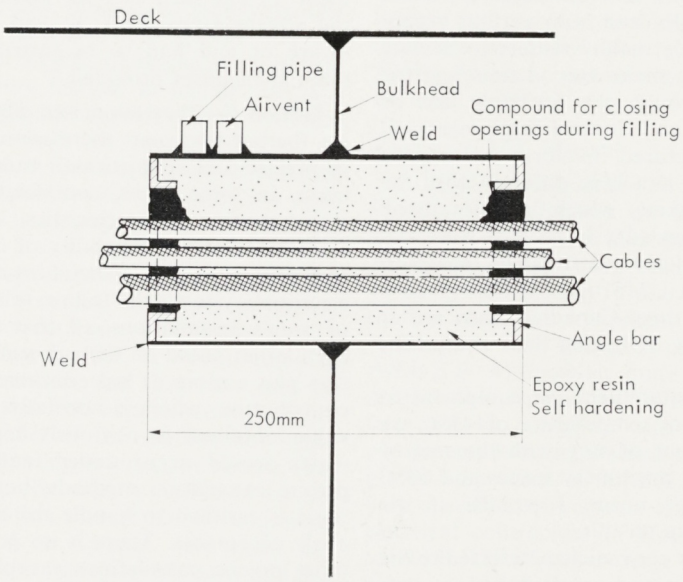


FIG. 4

or deck. Around the cables syndanio plates are fitted. The space around the cables between the forward and aft end syndanio plates is filled with an oil- and heat-resisting compound.

The forward syndanio plates are then pressed by means of a clamp attached to the gland by bolts.

Fig. 4 shows a drawing of a fireproof cable penetration using an epoxy resin. It consists of a ring welded through a deck or bulkhead. The cables are pulled through this ring and at the ends of the ring the openings are closed by a compound. Subsequently the ring is filled through a filling opening with a self-hardening epoxy resin. After some hours the epoxy resin is hard and the cable penetration ready. Besides the standard types of cable penetrations mentioned above capable of withstanding an A60 bulkhead test fire, there are various other ways of making fireproof cable penetrations. They are all based on the principle that cables are led through packed boxes. The boxes are filled with incombustible material, e.g. asbestos, such that the fire-resisting or fire-retarding properties of the division are not impaired.

MR. F. B. MORT (Montreal)

The Author is to be congratulated on his ability to condense, in less than 90 pages, a survey covering the wide field of electrical power engineering as applied to ships.

While I am in agreement with most of the Author's remarks and suggestions there are a few points I would like to draw attention to, mainly based on the North American attitude to ship's electrical installations.

The I.E.C. publication 92 referred to by the Author, while not unknown in North America, is seldom referred to by consultants, shipbuilders or manufacturers and the I.E.E.E. publication No. 45 "Recommended Practice for Electrical Installations on Shipboard" is still regarded as the basic guide for ship's systems, in conjunction with the relevant Classification Society's Rules.

A major problem in this part of the world arises from the fact that marine electrical equipment amounts to a very small fraction of the manufacturers' sales and with certain exceptions it is very difficult to persuade manufacturers to deviate from their standard product or to make special tests just for marine equipment. A glance through the Society's lists of Approved Fuses, and Instruments and Control Equipment will show that no equipment manufactured in North America is at present included. The situation is a little different with the List of Type Listed Circuit-Breakers, which includes many American breakers, but to my knowledge in no case were any tests specially made to obtain inclusion in this list. However, the current building of ships with UMS notation has given a spur to some manufacturers and three Canadian firms are at present investigating the possibility of having their equipment approved by L.R.

With regard to the Society's requirement for equipment to be based on a cooling air ambient temperature of 45°C we seem to be gradually becoming out of step with the rest of the world where 50°C ambient for machinery spaces and 40°C for accommodation spaces is the norm. I wonder if the Author has any comments to make on this.

My remaining comments are, for convenience, referred to the section numbers given in the paper and are as follows:—

**Section 3—Machines.** While in Canada we have had very little trouble with rotating machines which can be basically attributed to defective insulation, we have had during the past three years a number of failures, or incipient failures, due to slack cores on d.c. generator armature shafts or spiders and fractured winding overhang support brackets. These were all, with the exception of the last mentioned item, on machines manufactured in Europe. All the machines were driven by diesel engines and the failures obviously were the result of cyclic torsional oscillations which may or may not have been excessive. In some instances, however, the method of keying the cores to the shaft or spider was inadequate for a diesel-driven machine. The recent addition to the Guidance Notes in Chapter R(E) paragraph 112 of the Rules should help to mitigate this type of failure, but I wonder if the Author would agree to my suggestion that Section M 4 of the Rules for rotating machinery should draw attention to the aforementioned Guidance Notes.

**Section 4—Switchboards.** I think that the reference to "(1) Control *and protection* of generator circuits" might be misleading, as very few marine installations are provided with generator circuit protection in the true sense, i.e. there is normally no electrical protection for faults in the generator windings or the connecting cables to the generator circuit-breaker and the Rules do not require this. Accordingly, I would suggest that this item might be amended to read "Control of generator circuits". It should be made clear that the generator circuit-breaker only provides protection against over-currents and short-circuits derived from the load side of the breaker including switchboard busbar protection and protection against feed-back from healthy parallel connected generators into the faulty generator or generator connections.

I cannot completely agree with the Author's suggestion that all a.c. installations with parallel connected generators be fitted with automatic synchronising equipment. While a good case can be made for certain types of ships to be so fitted it seems to me that, so long as there are engineering personnel on board ships, there should be no problem manually synchronising generators. In fact the only problem experienced in Canada has been on ships fitted with automatic synchronising equipment. In one such case the automatic equipment failed during the voyage from the U.K. and the ship's personnel were not aware of and had to be instructed in the operation of the manual facilities provided.

**Section 5—Protection and Short-Circuit Calculations.** During the last few years there seems to be a trend to get involved in precise and sophisticated calculations which are dependent upon, in some cases, completely unprecise assumptions and stated machine characteristics, and if we are not careful the assessment of the capability of circuit-breakers, fuses, busbars and cables to handle the short-circuit currents in every given electrical system will follow this trend. In the great majority of ship's installations all that is required is a very simple calculation based on the sub-transient reactance of the generators plus a more or less educated guess at the motor feed-back contribution, which is normally relatively small. The resultant value obtained is obviously higher than the actual current which would occur under fault conditions or by the more precise calculation methods, but if the equipment being supplied is certified to handle the high value obtained it is obviously acceptable. There is no point in attempting any further more precise calculations except in the few installations proposed where there is some doubt about the capability of the equipment. I wonder if the Society has any records of failures which can be attributed to inadequate interrupting capacity

of equipment, especially since 1962 when the Rules first dealt with short circuit currents realistically.

I agree with the Author that one of the main problems with protective equipment is to establish that adequate discrimination has been provided between protective devices. We, in North America, have particular difficulty in obtaining discrimination between standard air-break circuit-breakers, normally used as generator breakers and moulded case breakers which are used for nearly all feeder circuits. In this connection the Author's suggestion to carry short-circuit tests on the actual installation on board the ship would probably cause apoplexy to the shipbuilders in Canada. We normally settle for a composite set of discrimination curves.

We have had many cases where the generator breaker instantaneous and/or short time delay trip settings, proposed by the switchgear manufacturer, were far too high in relation to the instantaneous and sustained short-circuit capability of the generator and I fully endorse the Author's reference to this important point. On the other hand, where special discriminating arrangements are proposed, it is important to ensure that the settings of long and short time delayed tripping devices will be within the generator manufacturer's stated current/time capacity of the machine, i.e. to trip the breaker before damage could occur to the insulation.

**Section 6—Motor Control Gear.** It is becoming a general practice in Canada to provide large motor control centres, often built as common back-to-back units, and in some ships close coupled direct to the main switchboard without a main feeder breaker. As the M.C.G. is normally built by a separate manufacturer, specialising in this type of equipment, it becomes important to make sure that this manufacturer is fully aware of the fault levels his equipment will have to be designed for, including adequate bracing of the busbar system.

**Section 7—Cables.** In Canada practically all marine systems are now installed with cables having cross-linked polyethylene insulation, with either a neoprene or PVC sheath, plus in most cases a bronze wire braid. Although ethylene propylene rubber insulated cables are commercially manufactured here, only one manufacturer has shown any interest in supplying this material for the marine field, and it would appear that the only advantage EPR has over XLPE, including cost, is that the finished cable is rather more flexible to handle. Perhaps the Author could comment on the European attitude to these two insulation materials. It could be mentioned that in Canada, where the winter ambient air temperature at some of the building yards can be as low as $-30°C$ special low temperature PVC compounds are used, capable of withstanding the cold bend test at $-40C°$.

Another point of interest mentioned by the Author is the statement that the ageing performance of XLPE insulating compounds is affected by copper catalysis. One of the world's largest suppliers of XLPE insulated cables, in North America, has stated on a number of occasions that they have had no evidence from their own tests and field experience to indicate such ageing occurs and I wonder if the Author has come across actual evidence of this, bearing in mind, of course, that the European compounds may be slightly different to the American product. I might mention that of the cables having XLPE insulation manufactured in Canada only those for marine applications have tinned or coated conductors, and this is only being done at our request.

**Section 9—Tankers.** I have noticed with interest the recent proposals by various authorities to regard the zone on the open deck over all cargo tanks including end zones, up to a height of 8 ft. above the deck, as a dangerous space and I wonder if our Rules will be modified in the not too distant future to embrace this philosophy.

With regard to electrical machines and in particular switchgear, which in some instances may become more difficult to locate in safe spaces if some of the proposed changes have to be implemented; has the Author any comments on the use of continuously air-purged equipment in lieu of certified flameproof enclosures.

**Section 11(c)—Reconditioning after Sinking.** A few years ago we had occasion to deal with three ships which had been completely submersed, for periods between two and six months. Although all these ships were submersed nominally in fresh water, by the time they had been salvaged all the electrical equipment had become coated with mud and a layer of oil.

The electrical equipment was treated generally as indicated by the Author, in one instance only the generators were rewound at the owner's request, the butyl insulated cables were dried out in place by passing low voltage current through them and the small amount of varnished cambric insulated cable fitted replaced.

The switchboards were completely stripped and rebuilt with all the old components, with the exception of a few potential transformers and instruments, which were renewed. Before reinstalling, the machines were all run under no-load conditions and the circuits tested, including a high potential test at slightly below the normal voltage for new machines. The rebuilt switchboards were fully tested as for new equipment.

Since going back into service these ships have all performed satisfactorily and without any electrical difficulties which could be attributed to their spell under water. It should be mentioned, however, that all the above ships had been in service for less than two years prior to their sinking and the insulation was accordingly in good condition.

**Section 12—Factory Tests.** I would like to endorse the Author's suggestion that it is unnecessary to normally insist upon a full type test, including temperature rise, on a batch of duplicate machines. We have great difficulty in persuading North American manufacturers that such tests are necessary on each machine.

### Reply to Mr. Mort

A.I.E.E.E. publication No. 45 "Recommended Practice for Electrical Installations on Shipboard" (edition 1967) is not unknown in Western Europe as quite a few ships for North American owners have been built here in recent years. It is somewhat surprising to learn that in North America special marine electrical equipment is difficult to find and that the tendency is very strong to use standard industrial equipment. A.I.E.E.E. 45 includes quite a few specific requirements for shipboard equipment and it is difficult to see how this specification can be complied with when using standard industrial equipment. It is understood that even the thickness of battery plates is specified in A.I.E.E.E. 45. It is also understood that very specific requirements are given for cables. It is stated by electrical contractors in Holland that installations according to A.I.E.E.E. 45 are at least 15 per cent more expensive than identical installations made to European classification and statutory requirements. It is understood that this is mainly due to the price of the specified cable types and the amount of working hours needed to install and finish these cables.

In fact it is thought by our shipbuilders that A.I.E.E. 45 is an old-fashioned specification, particularly as far as the section on cables is concerned.

The Author finds it difficult to give a strong opinion on Mr. Mort's remarks on ambient temperatures. It is possible to agree with 40°C as maximum ambient temperature for accommodation spaces as on almost all ships now being built the accommodation quarters are fully air-conditioned.

In view of our experience obtained over many years it could be argued that 45°C, at least for power equipment, is a suitable figure. However, engine rooms tend to become warmer due to various reasons, such as increased propulsion and auxiliary power in smaller engine rooms and the introduction of unattended machinery spaces which tends to result in less control of ventilation and temperature because the engineers are not so much concerned with it. In view of these arguments it could be worthwhile to consider the introduction of 50°C as the ambient temperature in machinery spaces, instead of 45°C. This would result in a decrease of 5°C in the maximum allowable temperature rises of machines and other power equipment.

In view of the failure rate experienced with electrical machines, particularly motors, this would certainly be welcomed by some shipowners.

The Author agrees with Mr. Mort's suggestion to have a cross-reference in Chapter M of our Rules to the guidance notes on torsional vibration included in Chapter R(E).

In general it would perhaps be worthwhile to have more cross references in Chapter M (and L) to other Rule Sections and paragraphs.

The Author cannot fully agreed with Mr. Mort's remarks concerning the reference to "(1) Control *and protection* of generator circuits". It is considered that a generator overload and short-circuit protection, although not protecting against internal generator faults, might protect a generator against burning out due to an external fault, e.g. a main switchboard fault.

In this sense the word "protection" is used in relation to generator circuits and this would not be fully covered by using the word "control" only.

The Author agrees with Mr. Mort that his statement on automatic synchronizing equipment was perhaps a bit too strong. It was caused by a few failures experienced not so long ago and by the impressive lack of knowledge and know-how found with engineers during the commissioning and trial period of newbuildings, particularly smaller ships.

Regarding short-circuit calculations the Author agrees with Mr. Mort that there is no reason to make precise calculations when it can be easily shown that the protective devices are capable to handle the highest fault currents or when the available machine data is based on unprecise assumptions. This last point again is a reason to require that machine manufacturers carry out sufficient testing to determine the short-circuit characteristics of their machines.

The Author cannot reply to Mr. Mort's question concerning our Society's records of failures which can be attributed to inadequate interrupting capacity of equipment, however, it is understood that recently on a ship classed with another Society damage was caused to a main switchboard because breakers had insufficient interrupting capacity. It concerned a case where moulded case breakers were used with insufficient making capacity. For insulation of cables it would appear that in Europe ethylene propylene rubber will be leading for the forthcoming years. It is argued by some manufacturers that cross-linked polyethylene is better than EPR in respect of points as mechanical resistance, oil resistance and ageing. However, the process of manufacturing conductors insulated with cross-linked polyethylene seems to be rather difficult and this could be the reason that most manufacturers prefer to use EPR.

The Author cannot support his statement concerning the ageing performance of XLPE compounds and copper catalysis by own experience. This statement was induced by information received from our Head Office.

When it is necessary to use electrical equipment in areas where explosion danger exists the Author would prefer the use of pressurized, continuously air-purged equipment rather than certified flameproof enclosures.

In his opinion it is easier to maintain a certain safety standard by air purging than by using flameproof enclosures. Of course, adequate means should be taken to interlock air purging with the operation of the subject equipment but that can easily be done. In general, however, it is the Author's opinion that no electrical equipment other than intrinsically safe equipment should be used in such areas unless it is really unavoidable.

Hydraulic and pneumatic systems are to be preferred.

### Mr. F. D. S. McCRUDDEN (H.Q.)

Reference has been made in the paper to the approval of cables. It is as well to note that it is not the practice of the Society to approve particular types and manufacturers of cables. Approval is only given to the types of insulating and sheathing materials. Provided that the insulating and sheathing of cables are of approved materials, no objection is made to the use of such cables on ships classed with the Society provided that the quality of the materials and cable construction comply with the requirements of the Rules or an approved standard.

We at Headquarters can check that the manufacturers' specifications comply with a recognised standard but the onus must be on the local surveyors to ensure quality control. I submit that the local surveyors should witness tests as detailed in Section M 8 of the Rules during initial stages of the manufacture of a cable and if found satisfactory subsequent similar cables may be accepted without the prescribed tests being witnessed by the surveyors. However, it would be advisable for periodic checks to be made to ensure that the workmanship and quality of materials are maintained.

Turning now to the internal wiring of switchboards, I notice that it is the practice of the Author to stipulate that such cables should be suitable for an ambient temperature of 65°C. This temperature is in excess of Rule requirements and also precludes the use of general purpose PVC insulated cables. I am not aware of any failures which could be attributed to this type of insulating material and would therefore welcome any evidence the Author may have to substantiate his requirement.

I have also failed to appreciate the significance of the flame retardant properties of bunched cables compared with that of a single cable and I would appreciate an explanation from the Author on this subject.

Mention has been made of new materials that are becoming available and the need for service experience before general approval is given to their use but no mention is made as to how this service experience should be monitored. It would

seem to me that there is a need for a procedure to be instituted to collate such information and other information which may be of interest thus providing invaluable assistance to the Headquarters Staff when dealing with queries and plan approvals.

### Reply to Mr. McCrudden

The Author fully agrees to the procedure of cable inspection as proposed by Mr. McCrudden. It could well be that shipowners and shipbuilders expect that we have some sort of inspection of cables used on their newbuildings and in fact at the moment in most districts we have nothing of this kind. Regarding internal wiring of switchboards it may be explained that the suggested requirement of 65°C is based on the assumption that the temperatures inside switchboards and in particular in the direct neighbourhood of heat dissipating power equipment could well reach such value.

This does not necessarily mean that the use of general purpose PVC insulated wiring is precluded by this because, in fact, most general purpose PVC's can withstand higher temperatures in practice than required by Rules or specifications and further because internal wiring of switchboards is normally used at a much lower current than the rating would allow. This last point is particularly applicable to control wiring and wiring of electronic equipment.

On the other hand the fact that internal wiring of switchboards has to withstand high temperatures is recognised by many cable makers, such as those manufacturing EPR–CSP, butyl–PVC, or high temperature PVC wiring. For instance it is understood that in Scandinavia wiring type TP100 is very popular for ship's switchboards and that wiring can withstand temperatures of over 100°C.

Ship's fires as well as laboratory tests have proven that cable bunches are less flame retardant than one would expect from flame tests carried out on a single cable of the same type. This is particularly so for cables without armouring or braiding. Perhaps this is due to the presence of a relatively large amount of combustible materials in a cable bunch and maybe because the openings between the cables in a bunch operate as "chimneys".

This increased fire danger given by cable bunches has recently been recognised by I.E.C. Sub-Committee 18A, dealing with ship's cables. An addendum to I.E.C. publ. 92–3 will be issued which will read as follows:—

> "Wherever the risk of fire propagation is high, for example in high vertical runs of bunches of cables, special installation precautions should be taken to prevent propagation of fire even if these cables are declared 'flame retarding'."

Such special installation precaution could be the extra fire stops proposed in Section 8 of the paper.

### Mr. S. SARKAR (Birmingham)

Mr. Ir. W. de Jong must be congratulated on his paper which I am sure will be of great help to our many colleagues who are not specialists in the electrical field and also to the newly joined electrical engineer to carry out the survey work and apply the rules in a practical way.

The following remarks are intended in the same spirit.

The Author has mentioned that the main circuit-breakers are often motor-operated either direct or via a spring. It is not clear what the Author means by the term direct as, in the writer's knowledge, all motor-operated breakers are spring-closed. Perhaps the Author would elucidate this point further. I would like to mention here that in ship installations the practice in the U.K. is to use solenoid closed breakers. This type of breaker has the advantage over the motor-operated spring-closed, in that the closing mechanism is very much simpler and hence the maintenance is easier and likely to give less trouble. Further, in case of failure of main generator (or circuit-breaker), i.e. for loss of voltage on the main busbars, the preferred arrangement in the U.K. is to start the emergency diesel generator automatically, and when the voltage rises to, say, 90 per cent, the diesel-breaker closes automatically to establish the supply on to main busbars by the diesel generator. This breaker is controlled by a three-stage auto reclose relay so that in case the breaker fails to latch for the first time for mechanical reason or otherwise, the relay is capable of giving two more consecutive impulses to close the breaker. I would be glad if the Author could let us know if this is a standard feature in his country. If so would he kindly explain, as I feel this feature is difficult to achieve for the type of breaker mentioned, in view of the long time required to charge the spring by the motor (usually 30 seconds).

In new installations of a.c. switchboard it is now standard practice to use withdrawal type of breakers, therefore the provision of isolation feature between the breaker and the main busbar, as mentioned by the Author, is a back-dated practice. Will the Author explain whether, in his country, this feature is still extensively used. It will be appreciated that the withdrawal type of breakers is preferred in any installation, from the point of view of simplicity of maintenance as well as the advantage of interchangeability in case of emergency.

With regard to automatic synchroniser with manual operated breakers it is not quite clear how the breaker could be closed when the machines are not in synchronism. Surely the circuit could be so arranged that the breaker could be closed, so long as the closing order is maintained by the synchroniser and should the breaker be closed at any other moment, it will operate "Trip Free".

The idea of using contactors parallel to slow closing breakers for synchronisation is no doubt a probable solution, but surely is not a sound engineering practice. The closing time of breakers available in the U.K. is well below 100 ms and are successfully used as generator-breakers without any problem of synchronisation. The frequency difference in practice could be reduced well below the figure of 0,5 c.p.s. mentioned by the Author within a reasonable time and I have not come across any appreciable problem of synchronisation.

### Reply to Mr. Sarkar

Not all motor operated circuit breakers used in the Author's district are spring closed. Some breaker manufacturers like Siemens and Merlin et Gerin also make breakers with a direct motor operated closing mechanism. This method is not favoured by the Author in view of the relatively long closing time.

Although solenoid closed breakers have certain advantages as rightly explained by Mr. Sarker, the following unfavourable properties of such breakers may also be noted:—

(a) Large amount of energy needed to operate the solenoid.

(b) Heavy shocks arising in the switchboard when a large breaker of this type is closed.

(c) Such breakers are usually rather large.

It has been experienced that due to the shocks mentioned under (b) the fusing wires of control fuses fitted in a generator breaker compartment blew at the moment the breaker was operated.

As far as the Author knows it is not a standard feature on the Continent to use 3-stage auto reclose relays in conjunction with emergency generator breakers. It is quite common to allow three starting attempts for the emergency generator engine but it is not considered necessary to have this same feature for the closing of the breaker.

The Author can agree with Mr. Sarkar that it is preferable to use withdrawable type breakers instead of fixed breakers provided with off-load isolators. However, it is not quite justified to say that the use of fixed breakers and isolators is a back-dated practice. When properly applied this method offers about the same advantages, and it may further be noted that in fact our Rules do not require either of the two methods. Perhaps our Rules are back-dated in this respect.

Concerning the question of the use of automatic synchronisers in connection with manual operated breakers, it may be explained that the problem is that some automatic synchronisers *maintain* the closing order for a short time *after* the machines were in synchronism. Should at that moment the breaker be closed manually the auto synchroniser would not prevent it. For that reason such synchronisers can only be used if they automatically give a closing order to the breaker.

## Mr. T. E. SHORE (H.Q.)

The Author has made reference to the high torques which can arise under short-circuit fault conditions or due to faulty synchronising of a.c. generators. Reference to the curves in Fig. 5* indicates that for a large turbo-alternator the conditions of highest torque occurs when mal-synchronising takes place at 120° phase error resulting in a torque that can be 15 × f.l.t., but this value is dependent on the reactance between the machines. The torques set up in this manner can be greater than those from a short-circuit fault as this is similar to mal-synchronism with 180° phase error which could give rise to torques up to 13 × f.l.t.

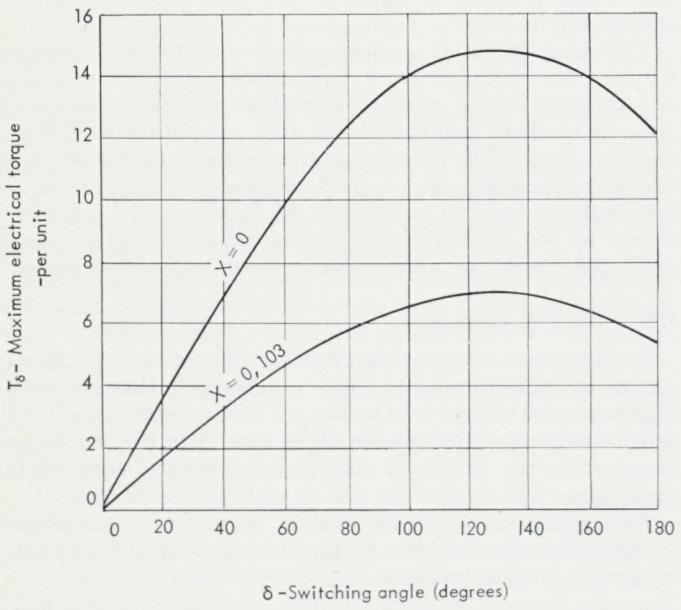


Fig. 5

Tests on marine salient pole generators have shown that under short-circuit fault conditions torques of the order of 13 × f.l.t. have been experienced. It is reasonable, therefore, to accept the curves for smaller alternators used in marine applications especially as the reactance between machines is usually negligible.

It is a requirement that any electrical system should be capable of withstanding the effects of short-circuit faults. The testing of generators under short-circuit conditions is quite common and perhaps it is time, therefore, that manufacturers of prime movers be required to carry out tests to ensure that the "mechanical end" is capable of withstanding the torques that can be developed under these conditions.

It may be as well to ease the mechanical engineer's mind a little by saying that these torques are oscillatory in nature and are only effective for short periods. The energy required to shear the shaft is the product of torque and time therefore the condition is not as severe as that which would occur with a sustained high torque.

When dealing with discrimination the Author used Fig. 13 on page 19. It should be pointed out that this type of diagram should be used with certain caution as the curves shown for fuse and relay characteristics are only true for currents of constant magnitude. It is energy which is required to operate those devices therefore it is more correct to use the area encompassed by these curves. If the generator fault currents are superimposed on the diagram it can be seen that due to the decrement of the current it is not constant. If the intersection of current and relay or fuse curves are used for operating points a false time will be given. Generators with long time-constants will give rise to enhanced errors when using this procedure.

Looking at Fig. 11, page 16, there appears to be no decrement in this generator current as the subtransient and steady state currents are of the same magnitude, perhaps the Author would like to state if this characteristic is common.

Whilst referring to discrimination it would be interesting to learn from Mr. de Jong if the shipyards in Holland use these curves when setting the system relays or is it done by rule of thumb.

The paper mentions the use of thermistors for motor protection, as some manufacturers are considering the use of thermistors for generator protection it would be interesting to know if the Author has any experience of this and, if so, how was the problem of ensuring discriminative action with feeder breakers overcome.

On the point of testing circuit-breaker relays I fully agree with the comments in the paper that they should be tested at time of building and at successive surveys but I doubt if many ports could provide the necessary equipment, in fact there are a large number of ports who cannot even produce a suitable reactive load for testing generators. Perhaps in Holland Mr. de Jong is in a fortunate position as he states that the majority of work is carried out by a few large contractors who are capable of supplying the necessary equipment; the size and geography of the country could also make the transport of the equipment an easy task.

* Wood, A. J., "Synchronising Out of Phase". Trans. A.I.E.E. Paper 56–1013. Oct. 1956.

## Reply to Mr. Shore

The Author is very glad with Mr. Shore's valuable contribution regarding torques which may arise under short-circuit fault conditions or due to faulty synchronising of a.c. generators. He particularly agrees with Mr. Shore's attempt to ease the mechanical engineer's mind in respect of those torques arising on the prime mover. The Author has attended quite a few short-circuit tests, has occasionally seen generators being paralleled when out of synchronism and has heard about many major short-circuit faults as explained in Section 5 of the paper. In none of those cases did the prime movers sustain damage. In a single case bolts of the coupling between generator and prime mover were broken.

The Author agrees with Mr. Shore's notes concerning the use of discrimination diagrams. The curves shown for fuse and relay characteristics are drawn for currents of constant magnitude.

In practice the fault currents have no constant magnitude and this must be taken into account when determining the tripping time from the curves.

This is not serious as far as discrimination is concerned because if the tripping time of one breaker or fuse is changed due to the decrement in the fault current, the tripping time of other breakers in the same system will also change and in general discrimination will not be affected. The generator short-circuit current curve shown in Fig. 11, page 16, has indeed no decrement. This is common for generators made by the subject manufacturer. In general, however, machines of this type have a decrement in the generator current. Normal values are: subtransient current $6+8 \times I_n$ and steady state current $3+5 \times I_n$. It is a general practice in Holland and Belgium that the builders use discrimination curves when designing installations. Perhaps it would be better to call such diagrams protection diagrams instead of discrimination diagrams because they serve a much broader purpose than only offering a method to check discrimination of protection. Such diagrams give on a simple and clear way a good picture about the whole protection system and the setting of the protective devices.

The Author has no experience with the use of thermistors for generator protection except a few cases where the thermistors for generator protection except a few cases where the thermistors were used for alarm purposes only.

The Author thinks that it is not advisable to accept thermistors for generator protection. The fact that thermistor protection cannot be tested is a major reason for this approach.

The Author is not so pessimistic about the possibility of providing sufficient test equipment for testing breakers at periodic surveys.

It should not be forgotten that a ship's special survey requires quite an organisation and many facilities like a drydock, heavy cranes, well equipped workshops for engine repairs, tanker cleaning facilities, etc. In comparison with this it is not an expensive or unpractical measure to require sufficient testing equipment for breaker testing.

The fact should not be overlooked that modern ships have electrical installations which are essential, complicated and quite expensive. The price of modern electrical installations may vary from 5 up to 12 per cent from the total price of the ship. Those factors justify proper testing and owners as well as Surveyors should get used to regarding this as a normal procedure like checking bearing clearances and the tightness of double bottom tanks.

## Mr. W. MORRIS (Tokyo)

I would like to congratulate Mr. de Jong on a most excellent paper which I am sure will be used for reference purposes for many years to come. It expresses the very essence of good marine practice and I applaud his clear cut views.

I would now like to make the following comments on details in his paper.

### Section 2

(a) **Paragraph (IV)(d)**

I prefer the "drip" method of determining the tracking characteristics of insulating materials. The I.E.C. Comparative Index is not easy to apply as a practical everyday tool to establish the acceptable level.

(b) **Paragraph (IV)(d)**(*b*)

I am surprised to read his comments that the creepage distances hardly affect the anti-tracking properties of bakelite. This is contrary to my experience and indeed some leading manufacturers compensate for the lower quality insulation of bakelite by increasing the creepage distances.

(c) **Approved Lists**

Since this paper was published, the lists have been extended. I believe that there is a case for a further extension to include cables, generators, motors, transformers and other major items. These could be dealt with by applying quality control techniques and approving works. This should ultimately result in a uniformity of acceptance standards and would benefit the shipowner and builders alike.

### Section 3

(a) **Paragraph (a)**

(I) The suitability of enamelled wires is a vexing problem. Mr. de Jong will be aware of the many breakdowns of machines of a particular German manufacturer which caused us to investigate this matter very thoroughly. The investigation showed that the higher temperature enamels did not always have the required mechanical strength to withstand the rough handling these wires receive during their installation into a machine. It became necessary finally to institute a quality control check on the wires after delivery to the machine manufacturers and in effect approving them for the subsequent manufacture. One method evolved by the Surveyor at the works to establish the quality of the wires was to immerse random selected wires in water, apply a voltage and then note the voltage at which they broke down. It was most instructive and a "comparative index" was soon made to our satisfaction.

(II) Laminates. The temperature effect on the weakest layer must be considered and also the final effect on the laminate when the weaker layer has broken down.

### Section 4

All connections to the main bars should be fully protected against short-circuit. The method suggested of fitting fuses to the bars is in my opinion the best. An alternative, which is not greatly favoured, is to arrange the connections so that a short-circuit between them is not possible. This can be done by making them fully insulated and having large clearances. The quality of the supports and their number should take into consideration the dynamic effects of an adjacent short-circuit.

I agree with his remarks regarding automatic synchronising equipment. I would, however, require that the voltage of the

incoming machine and the busbars be compared since there is no guarantee that the voltage increases at the same speed as the frequency which the omission of this link in the automatic synchronising command chain implies.

I would also recommend that automatic synchronising devices should only be used with breakers having a maximum total closing time of 50 milliseconds. All synchronising chokes should be thermally protected and I know of several instances where this omission resulted in serious damage to the switchboard. Where earthed control circuits are used, care should be taken in the circuitry that an earth fault will not inadvertently cause the control circuit to operate.

I was interested to note that Mr. de Jong also uses a curve relating the power factor to the doubling (peak) factor. As far as I am aware this does not appear in any text book but it saves considerable time in calculating the peak factor. This is, of course, required in order to calculate the making capacity of the breakers.

Discrimination of operation between moulded case circuit-breakers is very difficult to achieve and if this is required only those breakers should be chosen which have been satisfactorily tested together in cascade by the manufacturers for that duty.

Time delays are now, however, being fitted to moulded case breakers.

I agree with the Author's comments regarding generator protection and in particular to his remarks regarding the overload capacity of the diesel engine. Black-outs have occurred through the healthy diesel generator being unable to take the sudden overload caused by the failure of another generator and the preferential trips have not operated because of the drop in speed and the current drawn was slightly less than the setting.

Since the unhealthy generating set in these circumstances nearly always trips off on reverse power, there is something to be said for this relay to trip off the preferential load at the same time.

I agree that the preference tripping relay should not be set higher than 105 per cent F.L.

Time based selectivity for preferential and overload trips is a doubtful proposition and the Rules in my opinion intend that current selectivity is to be called for.

Let-through current is of major importance in designing switchboards and I fully support Mr. de Jong's contention that contactors are best protected by fuses. There are quick operating moulded case breakers on the market which would probably also meet the necessary requirements, however, they are generally more expensive, and require very careful selection to ensure that the amount of thermal power taken by the contactor is within its limits.

**Section 6**

The Rules do not call for remote isolators for control gear to be lockable provided the supply fuses can be removed.

I do not fully agree with the Author's view that external auxiliary wiring voltage should not exceed 250 volts, in view of the safety of personnel. The major problem with using a voltage above 250 is that the associated control apparatus such as thermostats and pressostats are not rated for this value. However, I see no problem with 440 volts for instance for push button control circuits provided the apparatus is properly designed.

The neatest way to get around the problem of multi-fuses for signal and pilot lamps is to make these a combined transformer-lamp unit with the transformer being short-circuit proof, i.e. a short-circuit fault on the lamp will not cause the temperature to exceed the limits permitted by the transformer insulation or the current to exceed the ratings of the connections.

I fully agree with the remarks regarding the automatic and sophisticated motor starter system. Very often they are not fully thought out and frequently control circuit connections are common to both essential duplicate drives which, of course, make them acceptable.

Thermistors either PDC or NDC offer probably the best thermal protection to motors and generators provided they are located in the "hot spot" areas of the windings. Care should, therefore, be taken to ensure that this is done by discussing this with the machine designers and agree the location with them on a type machine basis.

**Section 7**

There are many ships operating today which are fitted with butyl and EPR insulated cables and I believe with satisfactory results. It may, therefore, be desirable to define the term "oil resistant".

I believe that all cables should be type-tested in the presence of the Surveyors and these included in the Approved Lists. However, until this becomes a reality I agree that the cables should be inspected at the builders for make-up and construction. Generally, cables carry an identification thread or mark which also assists in establishing whether they are of an approved or acceptable type.

The construction and X sectional areas of switchboard internal cable connections are not specified by the Rules. However, they should be suitable to carry the prospective current and also thermal loads under short-circuit conditions. I cannot agree with the ambient temperature of 65°C stipulated by the Author since on modern ships today the switchboards are well ventilated and the temperatures are generally below 45°C. In assessing the current-carrying capacity of these connections it should not be overlooked that they are generally single-core conductors which allows for a higher rating. The thermal capacities under short-circuit are more important and it has been my practice to use the attached curves (Figs. 6 and 7) as a guide in assessing their suitability for the intended duty. However, in the cases referred to in Section 4, where the connections have been made "short-circuit proof", only the "let-through" energy need be considered.

I have carried out tests as per M 850 on PVC insulated and sheathed wires and have found them by this definition to be fully fire resistant. Perhaps, therefore, further consideration should be given to determine the proper test for establishing the fire resistance of a cable/wire since the present test is, in my opinion, inadequate.

**Section 8**

Whilst I fully agree with the Author's sentiment regarding the "usual" method of securing cables, regrettably this is no longer the case today. Generally, the cables are secured without consideration for future possible removal and replacement. Cable bands similar to those used for securing packing cases are frequently used and, of course, other patent type clips or supports—all having one main advantage—cheapness in production and installation. As the Rules permit them or properly said—do not forbid them—it is impossible to refuse them on board regardless of how one might mourn the passing of a craft.

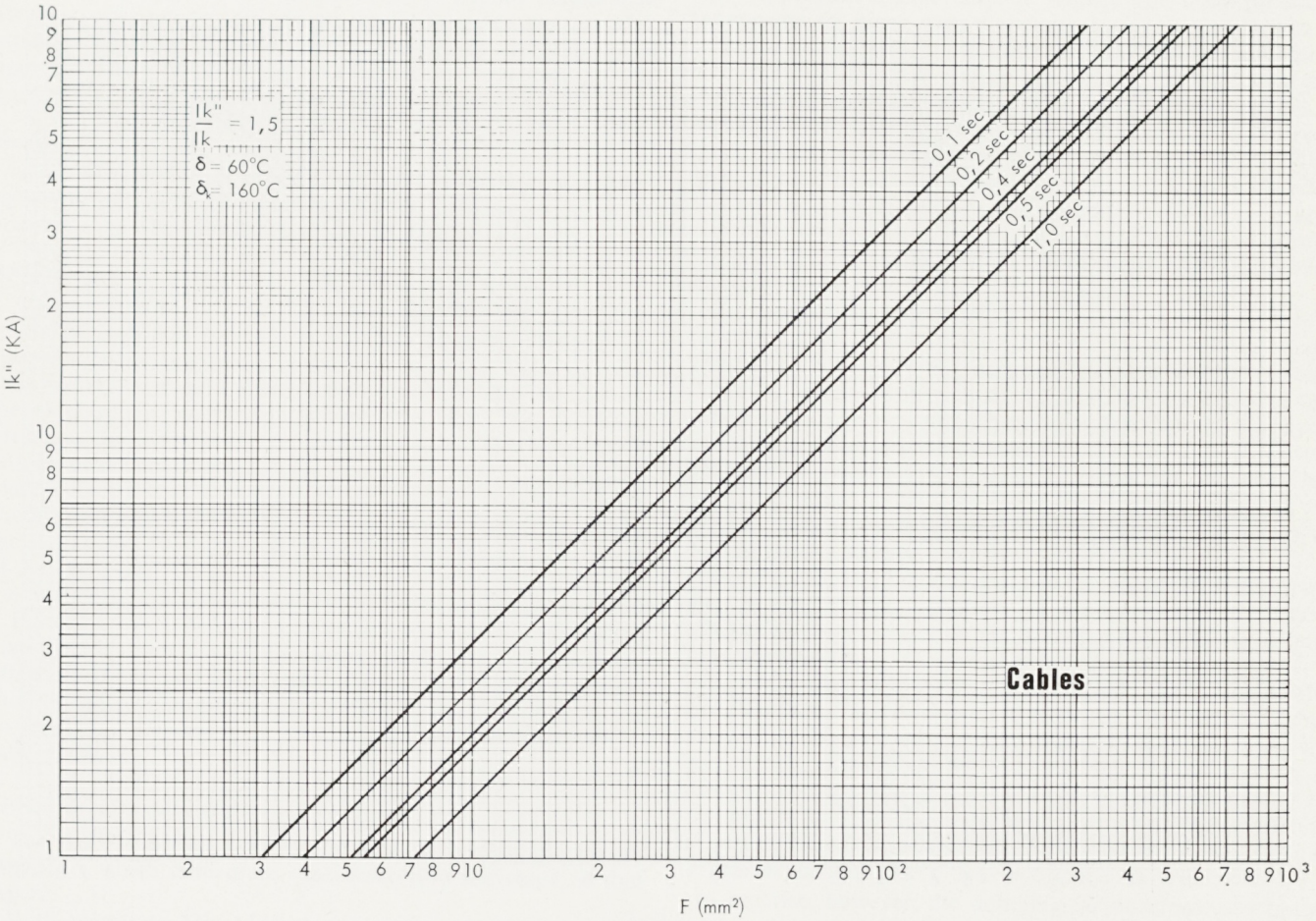
Ik" / Ik = 1,5
δ = 60°C
δx = 160°C
0,1 sec
0,2 sec
0,4 sec
0,5 sec
1,0 sec
Cables
Ik" (KA)
F (mm²)

FIG. 6

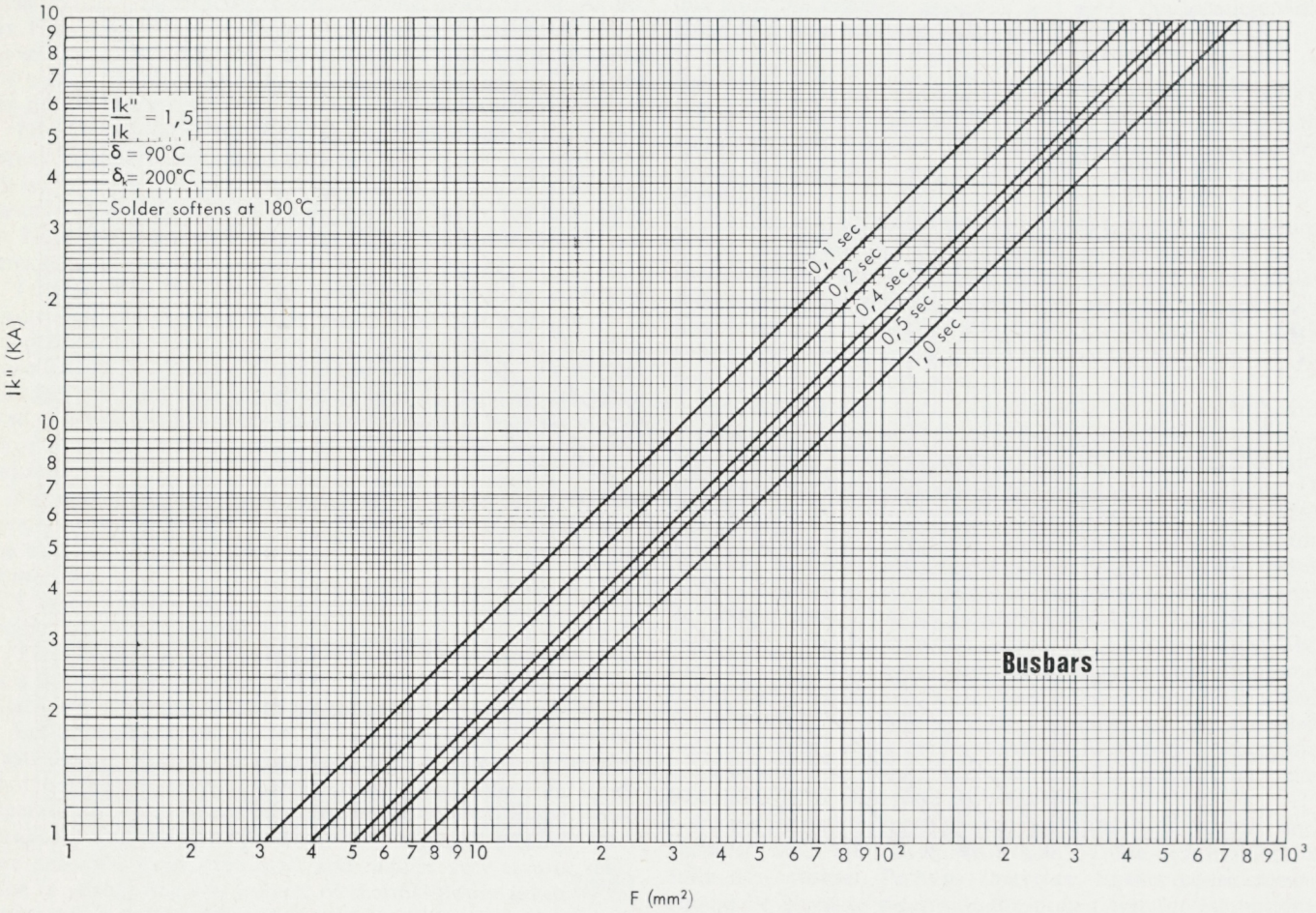
Ik'' / Ik = 1,5
δ = 90°C
δk = 200°C
Solder softens at 180°C
0,1 sec
0,2 sec
0,4 sec
0,5 sec
1,0 sec
Busbars
Ik'' (KA)
F (mm²)

FIG. 7

**Section 9**

One of the big problems today on tankers is the proliferation of electrical equipment and cables in dangerous spaces. In principle these have to be intrinsically safe with the attendant feature that the cables should be physically separated from other non-intrinsically safe cables. This point is generally not understood and is frequently overlooked with resultant costs when the changes have to be made. A further point is what is meant by physically separated and it has been my practice to define this as a 5 cm. separation. This allows a great deal of latitude in practice.

One of the major problems on tankers is to establish the dangerous spaces and the juxtaposition of vapour outlets and accesses/openings to safe spaces should be given very careful attention right at the beginning, starting at the ship plan approval stage since subsequent structural amendments are very costly and frequently difficult to achieve.

**Section 10**

A simple method of ensuring that the extinction of a pilot light will not cause the main navigation light to go out is to connect a parallel resistance to the pilot light.

**Section 13**

I also consider that an Electrical Engineer Surveyor is a specialist and for routine installation work and testing, a specialist is not required.

However, he should always be available for discussing with the shipbuilders and manufacturers the very real technical problems that arise today on the complicated electrical installations now being constructed. These discussions should take place before installation and/or manufacture commences. He should also pay visits to the new buildings fitting out and to the workshops from time to time with and/or at the request of his Engineer Surveyor colleagues so as to establish that the particular and specialised requirements are being met.

Finally, I would like to add that it should not be overlooked that the Surveyor's interpretation of Rule requirements very often affect the cost of the installations. Care should, therefore, be taken to ensure that the solutions to the problems that do from time to time arise are both economically and technically viable.

REPLY TO MR. MORRIS

The Author is glad with Mr. Morris's extensive and expert comments which contribute considerably to the value of this paper.

With regard to Mr. Morris's comments on the method of determining the tracking characteristics of insulating materials, the Author is not fully aware of the difference between the "drip" method and the method specified in I.E.C. 112. Also I.E.C. 112 uses a drip method to determine the Comparative Tracking Index.

With Mr. Morris also, the Author was surprised when he saw the test results which showed that the creepage distances hardly affect the anti-tracking properties of an insulating material, at least if it concerns a lower quality material. These results were, it may be remembered, obtained by tests under practical conditions and not in a laboratory. The insulating materials were exposed to normal outside air on the roof of a building, to sea air and amongst others also to polluted air inside a factory. A voltage was supplied over the surface of the materials and the time of breakdown was recorded. The results showed that for the materials referred to above a longer length of creepage path increased the period of time necessary for a breakdown but it did not prevent the breakdown.

The Author endorses Mr. Morris's views on the List of Type Approved Equipment, in particular as far as cables are concerned. Practical problems are, however, foreseen when this is to be applied for electrical machines and transformers. These items, except below a certain rather low rating, are not mass produced, but are usually made in small series. The quality of electrical machines is further very much dependent on workmanship. It is the Author's opinion that in principle Type Approvals should only be applied for mass produced components or items with a manufacturing process which is not too much dependent on workmanship. To a certain extent this last problem may perhaps be solved by approving the works quality control scheme in addition to type testing, but in our own interest and that of our clients, we cannot divert all our responsibility to the maker and limit our task to yearly flying visits. Cables, however, are very suitable items to be included in Approval Lists. These are mass produced and used in large quantities, the manufacturing is not dependent on workmanship and routine testing (to be carried out by an approved quality control department) is rather easy.

With regard to Mr. Morris's comments on automatic synchronising, the Author agrees that in case of full automatic systems the voltage of the incoming machine and the busbars should be compared in view of possible difference in speed of voltage and frequency rise. The system described in the paper, however, is based on the assumption that the automatic synchroniser is switched on manually when the engineer has ascertained that the machine has started and has obtained the correct frequency and voltage. In that case it is not necessary to compare the voltage signals.

As far as the Author understands the phenomena occurring when a synchronous generator is short-circuited, the curve relating the power factor to the doubling (peak) factor is only an approximation.

In theory the doubling factor is not only dependent on the power factor of the short-circuit path (d.c. time constant), but amongst others also on the time constant of the subtransient short-circuit current. As the subtransient time constant is dependent on machine design and not equal to all machines, it is impossible to make a theoretically correct curve relating the power factor to the doubling (peak) factor. Perhaps this is the reason that this curve does not appear in text books.

In practice, however, the doubling factor curve used in the paper is accurate enough and avoids a lot of extra calculating work when the peak asymmetrical s.c. currents have to be determined.

The Author is very glad with Mr. Morris's suggestion to have the preference tripping system also operated by the reverse power relay. This suggestion is worthwhile to be followed, particularly when the load balance shows that many kilowatts have to be disconnected in order that the remaining generator(s) are not overloaded in case one set fails.

The Author is afraid that the question of the level of control voltages is a typical matter of opinion. Technically, of course, provided all equipment is suitably rated, there is no problem. In practice, however, in the Author's opinion the average ship's engineer does not expect a voltage of 440 volts in a tiny limit switch, pressure switch or similar equipment and that in view of this the safety of personnel is at stake. It

should be realised that when one phase of an insulated ship's mains has an earth fault, the other phases have a voltage of 440 volt against against the ship's hull. Although it is admitted that voltages of 110 or 220 volts are also not harmless, it is thought that it is not a good practice to expose an engineer to the risk of touching 440 volts against earth when the man is adjusting a pressostat or carrying out maintenance to neighbouring equipment in the same panel or control desk. It is further considered that this interpretation could well be in line with clause M 202 of our Rules. It may finally be added that earth faults in ships are rather common, particularly when the ships get older.

The Author agrees with Mr. Morris that many ships have been fitted with EPR and particularly butyl insulated cables and up to now mostly with satisfactory results. The Author's statement that these materials are not resistant against oil is perhaps a little too strong, it should better have read "less resistant against oil". This is supported by laboratory tests and in view of this on ships built in Holland and Belgium the cable ends of butyl or EPR insulated cables are sleeved or taped where they might be subjected to engineroom air or other oil-laden atmospheres. The future will show whether this is superfluous or not.

The Author regrets that Mr. Morris cannot agree with a maximum ambient temperature of 65°C inside switchboards. Measurements on existing ships have clearly indicated that locally inside switchboards such temperatures can well occur.

Of course, such temperatures need not be expected in all switchboards but as a maximum level for the choice of equipment, particularly internal wiring, the Author considers that this is a reasonable level. Such temperatures may occur under the following circumstances: —

(a) In totally enclosed, cubicle-type, switchboards not sufficiently cooled by strong ventilating air currents passing the switchboard plating. In this respect care must be taken when such boards are located in control rooms because in those spaces, although possibly air conditioned, there are only very weak air currents and their cooling effect on switchboards is very limited.

(b) In motor control centres (group starter boards) unfavourably located such as in enginroom casings, in direct sunlight when the skylight is open, near boilers or steam-pipes, etc.

(c) Locally in switchboards containing heat dissipating equipment, such as lighting transformers, generator voltage regulating equipment, etc.

It is agreed with Mr. Morris that the present tests for flame retardant and fire resistant cables are not adequate. It is hoped that in the near future more realistic tests could be agreed upon.

The Author whole-heartedly agrees with Mr. Morris's description of the task of an Electrical Engineer Surveyor and the proposed co-operation with the Engineer Surveyors.

He would also like to support Mr. Morris's opinion on the possible effect of a Surveyor's recommendation on the cost of the installations. In this respect, however, it may perhaps be mentioned that it is not only the Society's duty to distribute the same printed Rule Books all over the world, but it is also to be closely watched that the interpretation of these Rules, particularly insofar as installation practices, workmanship, choice of materials and similar subjects are concerned, are kept equable in all our districts. To achieve this object some form of co-ordination, going further than checking plans and F.E. Reports, would perhaps be necessary.

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# SIMPLIFIED SHORT-CIRCUIT CALCULATIONS FOR MARINE ALTERNATING CURRENT NETWORKS

W. Morris and K. H. Klemm

Paper No. D1 (for written discussion) Session 1970 - 71

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# CORRIGENDUM

to Paper No. D1 (1970–71)

## SIMPLIFIED SHORT-CIRCUIT CALCULATIONS FOR MARINE ALTERNATING-CURRENT NETWORKS

by

W. MORRIS AND K. H. KLEMM

The formula on Sheet IV, pages 8 and 23, should read:—

$$\frac{1{,}05 \cdot U}{\sqrt{3} \cdot Z}$$

# SIMPLIFIED SHORT-CIRCUIT CALCULATIONS FOR MARINE ALTERNATING CURRENT NETWORKS

:MM

## ERRATA

**to Paper No. D1 (1970-71)**

by

W. MORRIS and K. H. KLEMM

1. The abbreviations for kilo-amperes and kilo-volts should be KA and KV, respectively. In some of the standard sheets and calculated examples these abbreviations are shown incorrectly as kA and kV.

2. At the bottom of pp. 4, 5 and 11:—

   machine-Manufacturer should read machine-manufacturer

3. At the bottom of page 4:—

   assesed should read assessed

4. On pp. 6, 7, 8, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23 and 25:—

   the symbol for the doubling factor should be $\kappa$, i.e. capital Greek kappa and not small Greek kappa.

< but which may feed power into the network conditions. All such sources of power must there- ed and taken into account in any calculation.

e of fault current which can flow in any network -circuit conditions is limited only by the imped- iat network. It is, therefore, important that the and reactances which vectorially combine to give nce of the short-circuit path, be calculated accur- marine installations, the resistances may not in gnored, since they often result in reductions to the pturing capacities of the protective devices and /e the calculated power factor of the fault path. ning fault values for the ratings of the protective s only necessary to calculate for the worst condi-

ıl peak value of the short-circuited current may be ole the peak value of the a.c. component and this ffect is dependent on the ratio Resistance (R)/ X) and is therefore related to the power factor of rcuit path.

ces for short-circuit protection considered in this ircuit breakers and fuses.

*Breakers*

cuit breaker has three major duties to perform t-circuit conditions. Firstly, if it is open, it may se on to the fault and "make" the fault current. f it is already closed when the fault develops it to open the faulty circuit and "break" the fault ially, it may have to carry the fault current until d relays operate. In the second of these three fault current in at least one phase will have con- symmetry if the breaker opens during the first few the inception of the fault. The operating times of s are therefore important.

going duties are described as:—

*Capacity*

ne current (I) that the breaker must make safely d on to a fault. To do this, the breaker must be thstand the electro-magnetic forces produced by lue of the current in one phase. This can, theoreti- high as twice the peak value of the symmetrical $2 \times \sqrt{2}$ (i.e. 2·828) times the r.m.s. value of the l fault current, depending on the doubling factor

*ng Capacity*

ne fault current ($I_k$) that the breaker must be able t safely with a specified voltage—depending on specification—across its contacts, after arc extinc- breaking capacity is therefore dependent on the oltage which appears across the open contacts at o, and therefore on the power factor.

king capacity is normally given as the symmetrical a.c. r.m.s. value together with the power factor of the test circuit. From this latter, the asymmetrical r.m.s. current which is actually broken can be calculated.

cient.

The source of fault power originates in all connected generating plants and machines normally taking power from

With certain breakers it is possible to relate their breaking capacities directly to the power factor so that the ratings may be converted from that certified to that of the actual fault circuit. As this conversion reduction factor C does not have universal application, however, it may only be employed with caution and should first be cleared with the manufacturer.

Low power factors are to be expected at points close to the source of power (e.g. main switchboard) and high power factors at remote points, this being due to the resistance values of the short-circuit paths.

(iii) *Short Time Capacity*

The breaker has to carry the rated symmetrical breaking current for a period determined by the setting of the time delay relays in the circuit, while another breaker (in series) is clearing a fault. In marine installations this delay would not be greater than one second and is generally determined by the settings of the generator breakers. Most National Standards require that this one-second rating be tested and certified. The breakers are to be undamaged by the heat generated.

(b) *Fuses*

Fuses also have to perform the same duties, but as they operate differently they are rated differently. They are given a breaking capacity rating which is the greatest prospective current that may be associated with the fuse under prescribed conditions of voltage and power factor, and is expressed as the symmetrical r.m.s. current. It also has a "cut off" feature, i.e. it operates so rapidly that it "cuts off" the current $I_d$ before it reaches its maximum value. Due to this it possesses complete making current release properties which can be compared to the "trip free" action of the circuit breaker.

This "cut off" feature also protects all down stream apparatus associated with the fuse (e.g. switch, busbars, connections, instrument transformers, etc.) from the full effect of the electromagnetic forces of the fault current and is of major importance in designing electrical installations. This electromagnetic force is proportional to the square of the fault current.

## 2. Procedure

As it is convenient to summarize the essential data necessary for the calculation of the fault current, a standard network diagram sheet has also been prepared which is to be completed to give a picture of the system to be investigated, and which shows:—

(a) All the sources of fault current with their principal parameters, e.g. rating, resistance, and reactances, etc.

(b) Size and reactance/resistance of the transformer.

(c) Cable cross sectional areas and connection lengths.

The faults normally considered are those occurring at the following locations:—

(i) Main switchboard.
  (a) Generator Breakers.
  (b) Outgoing Feeders.

(ii) Auxiliary switchboards or distribution boards.

(iii) Transformer secondaries and associated circuits.

Two standard calculation sheets have been prepared namely:—

(i) For parallel operating sources of fault power which require symmetrical components for resolving the equivalent impedance and power factor, and

(ii) For straightforward fault calculations where parallel paths are not involved and which therefore only require the vectorial addition of the reactances and resistances.

These sheets are completed from the network diagram and the attached data sheet for:—

(a) Cable resistances and reactances.

(b) Doubling factor/power factor curve.

With these two standard sheets any fault condition can be calculated and the result then transferred to the summary sheet for comparison with the ratings of the protective devices to be fitted.

As the reactances and resistances of generators and transformers are normally expressed as a percentage, it has been necessary for this calculation procedure, to convert them to ohmic values and the formulæ used have also been shown.

The fault currents have been determined by calculating the initial short-circuit a.c. current at zero time from the resistance and reactance of the circuit and from this value, the maximum peak asymmetrical short-circuit current during the first half cycle has been obtained. The network voltage U plus a 5 per cent tolerance for the voltage regulation has been used and the doubling factor read from the attached curves after the power factor of the fault has been calculated.

Consideration has only been given to the worst conditions.

The running motors have been converted into an equivalent generator with an output equivalent to 70 per cent of the running generators and having a percentage reactance and resistance of 33 per cent and 6 per cent respectively. These figures have been based on a 300 per cent motor full load current contribution to the fault and a fault power factor of approximately 0,2.

In the examples, the values of impedance chosen, like those usually quoted in practice, are applicable to a symmetrical three-phase fault, i.e. three phases short-circuited at the fault point.

## 3. Definitions and Symbols

3.1 The *breaking current* $I_k$ is the initial symmetrical short-circuit a.c. current which is the r.m.s. value of a.c. component of the short-circuit current extrapolated to zero time.

3.2 The *making current* $I_s$ is the asymmetrical short-circuit current which is the peak value of the maximum current loop (including the d.c. component) in any pole after commencement of short-circuit.
The value of $I_s$ is dependent on the instant in time when the short-circuit occurs and in these calculations $I_s$ is taken to be the maximum short-circuit current that can occur.

3.3 The *running motor* current is the contribution made to the fault current by all the motors simultaneously in service and has been assumed to be equivalent to 70 per cent of the running generators.

3.4 *Cut off*. If the melting of a fuse prevents the current through the fuse from reaching the otherwise attainable peak current of the first major loop, the fuse is said to cut off and the instantaneous maximum current obtained is called the cut-off current ($I_d$).

3.5 *Subtransient reactance* $X_d$ of an a.c. generator is the quotient of the phase voltage and the symmetrical short-circuit current $I_k$ resulting from a three phase short-circuit on the generator terminals, when operating at no

load and rated voltage.

The sub-transient reactance is generally shown as $x_d''$ and is expressed as a per unit value in terms of the machine parameters

$$\left[\text{i.e. } \frac{X_d''}{m\Omega} = x_d''\,\% \cdot \frac{U^2\ (KV)}{S_N\ (MVA)} \times 10\right]$$

3.6 *Resistance* =R. r=resistance per unit length

3.7 *Reactance* =X. x=reactance per unit length

3.8 *Impedance* =Z.

3.9 *Short-Circuit Power Factor Cos* $\phi_K$ is the ratio of the resistance to the impedance of the short-circuit path at the instant of short-circuit (i.e. Cos $\phi_K = R/Z$).

3.10 *Doubling Factor* $\kappa$ is dependent on the relationship of the resistance to the reactance (R/X) in the short-circuit path and indicates the degree of asymmetry to be expected on any faulty system. It determines the making current $I_s$.

3.11 *Transformer Short-Circuit Voltage* $U_k$ is the voltage which appears at rated frequency and rated current at the input windings when the output windings are short-circuited.

The per unit short-circuit voltage $U_k$ is the ratio of the short-circuit voltage $U_k$ to the rated voltage U.

3.12 *Transformer Resistance Voltage Drop* $U_R$ is the resistive component of the short-circuit voltage $U_k$. It is expressed as a percentage of the rated voltage U and is designated $U_R$.

3.13 *Transformer Reactance Voltage Drop* $U_x$ is the leakage reactance component of the short-circuit voltage $U_k$. It is expressed as a percentage of the rated voltage U and is designated $U_x$.

3.14 *Conversion Factor* C is the relationship between the doubling factor arising from the power factor of the circuit breaker test circuit to the doubling factor arising from the power factor of the faulty circuit and, in the Authors' opinion, may only be applied for reducing the breaking capacity rating.

3.15 Rated Apparent Power $=S_N$ (MVA)

3.16 Rated Current $=I_N$ (KA)

3.17 Rated Voltage $=U$ (KV) or (V)

3.18 Rated Frequency $=f$ (Hz)

## 4. Standard Calculation and Data Sheets with Examples

The procedure has been demonstrated on a 440 volts 3 phase 60 Hz installation having a connected generating capacity of 2850 KVA. This is made up of $2 \times 1125$ KVA and $1 \times 600$ KVA generators with $1 \times 1125$ and $1 \times 600$ KVA machines being required together to supply the working load. The second 1125 KVA machine is a standby. The motors running simultaneously have been estimated at approximately 70 per cent of the working generators and their contribution to the faults has been based on $3 \times$ full load current and a fault power factor of approximately 0,2.

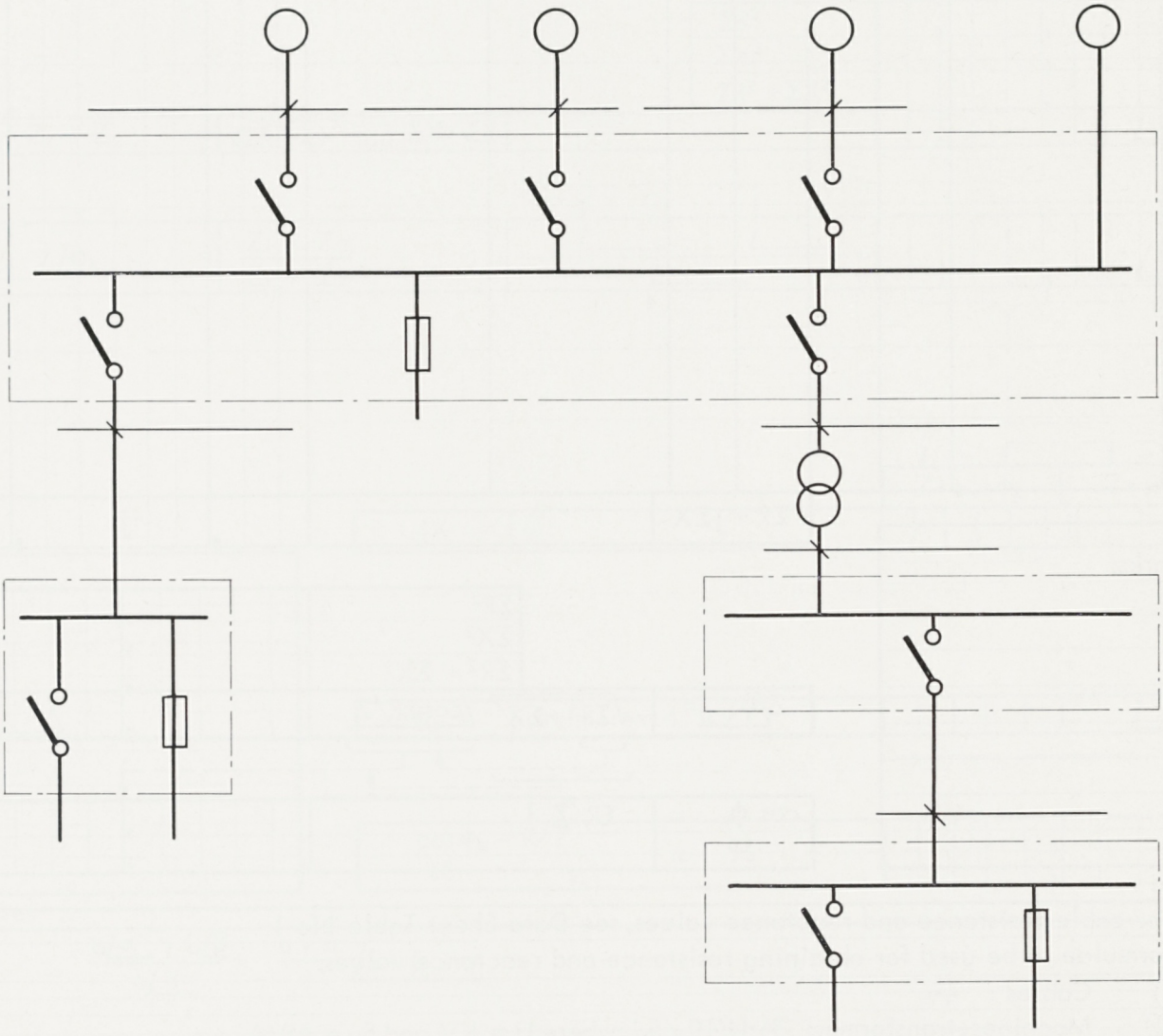
| | | Page |
|---|---|---|
| Short circuit A.C calculation | | |
| Network-diagram | | |
| Builder: | Yard No | |

| | |
|---|---|
| $S_N$ (MVA) | |
| $J_N$ (KA) | |
| R (mΩ)1) | |
| $X''_d$ (%)1) | |
| Number : | |
| | |

1) To be stated by machine-Manufacturer. Values per phase.
Resistance at 45°C. Running motors assesed on basis of 70% running generators, 3xFL current and ~ 0,2 fault power factor

Sheet 1a

| | | | | |
|---|---|---|---|---|
| Short circuit A.C calculation | | | | Page |
| Network-Diagram | | | | |
| Builder: | | Yard No | | |
| $S_N$ (MVA) | | | | |
| $J_N$ (kA) | | | | |
| R (mΩ) 1) | | | | |
| $X''_d$ (%) 1) | | | | |
| Number: | | | | |
| | | | | |



1) To be stated by machine-Manufacturer. Values per phase.
Resistance at 45°C. Running motors assessed on basis of 70% running generators, 3xFL current and ~0,2 fault power factor

Sheet 1b

Determination of resistances and reactances per phase for short circuit

Page

Point No

| Item | Designation | $l$ | $n/\square^2$ | $r$ 1) | $x$ 1) | R 2) | X 2) | R | X |
|---|---|---|---|---|---|---|---|---|---|
| | | m | $mm^2$ | $\frac{m\Omega}{m}$ | $\frac{m\Omega}{m}$ | mΩ | mΩ | mΩ | mΩ |
| | | | | | | | | | |
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| | | | | | | | | | |
| | | | | | | | | | |
| | | | | $\Sigma R + j\Sigma X$ | | | | | +j |

| | | |
|---|---|---|
| | $\Sigma R^2$ | |
| | $\Sigma X^2$ | |
| | $\Sigma R^2 + \Sigma X^2$ | |
| $Z/\phi_{K\ 3)}=$ | $\sqrt{\Sigma R^2 + \Sigma X^2}\ /\cos \Sigma R/Z$ | / |
| $\cos \phi_K$ = | $\Sigma R/Z$ | |
| $\partial\ell$ 5) | | |

Remarks:

Notes :

1) For cable resistance and reactance values, see Data Sheet Table No 1

2) Formulae to be used for obtaining resistance and reactance values;

I) Cables : $\frac{1}{n} \cdot r$

II) Machines, transformer; $\% \cdot U^2 \cdot 10 / S_N$ ; where U = KV and $S_N$ = MVA

III) Recalculation for other voltages ; $R_2 = R\ (U_2/U)^2$ ; $X_2 = X \cdot (U_2/U)^2$

3) $\phi_K$ = Short circuit angle

4) For busbar resistance and reactance values , see Data sheet Table No 2

5) For doubling factor $\partial\ell$ see Data sheet, Table No 3

Sheet II

Determination of resistances and reactances for short circuit point No for

parallel operating machines and associated cables.

Generator( ) + ( ) + ( ) + ( ) + Motor ( ) + ( )

Page

| Item | | $Z/\phi_K$ <br> $m\Omega/$ | R <br> $m\Omega$ | X <br> $m\Omega$ |
|---|---|---|---|---|
| 1 | $Z_1$ = (from page ) | | | |
| 2 | $Z_2$ = (from page ) | | | |
| | | $\Sigma R$ $\Sigma X$ | | |
| | | $\Sigma R^2$ <br> $\Sigma X^2$ <br> $\Sigma R^2 + \Sigma X^2$ | | |
| 3 | $Z_1 + Z_2$ = $\sqrt{\Sigma R^2 + \Sigma X^2}$ tan $\Sigma X / \Sigma R$ | | | |
| 4 | $Z/\phi_K$ = $\frac{Z_1 \cdot Z_2}{Z_1 + Z_2}$ | = 1) | | |
| | | | $Z \cdot \cos\phi_K$ | $Z \cdot \sin\phi_K$ |
| | $R + jX$ = | | | $+j$ |
| | $Z\phi_K$ = (from item 4) | | | |
| | $\cos\phi_K = R/Z$ <br> $\partial\ell$ 2) | | | |

Remarks :

Notes

1) $\frac{a/\alpha \cdot b/\beta}{c/\gamma} = \frac{a \cdot b}{c} /\alpha + \beta - \gamma$

2) For doubling factor see Data Sheet table No 3

Sheet III

| Summary | Page |
|---|---|
| | |

| Short circuit point | Calculation | | | | | | | Protective device | | | | | | | | Recalculated breaking capacity at calculated $\cos\phi_K$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Impedances from Page | Z | $\mathcal{L}$ | $\cos\phi_K$ | U System Voltage | $J_K'' = \frac{1{,}05 \cdot U}{\sqrt{3} \cdot Z}$ 1) | $J_S = \mathcal{L} \cdot \sqrt{2} \cdot J_K''$ | J Rating of fuse | Jd Cut off current of fuse | Rated Voltage | Breaker / Fuse, Index | Maker and type | $\cos\phi$ | $J_K''$ | $J_S$ | C 2) | $J_K'' = C \cdot J_K''$ red. |
| No | Page | mΩ | - | - | V | kA | kA | A | kA | V | - | - | - | kA | kA | - | kA |
| | | | | | | | | | | | | | | | | | |
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1) U (V)$_i$ Z (mΩ)

2) For determination of factor C, see data sheet, Table 3

Sheet IV

Date: Signature:

| | Page |
|---|---|
| A.C short circuit calculation<br>Data Sheet 1 | |

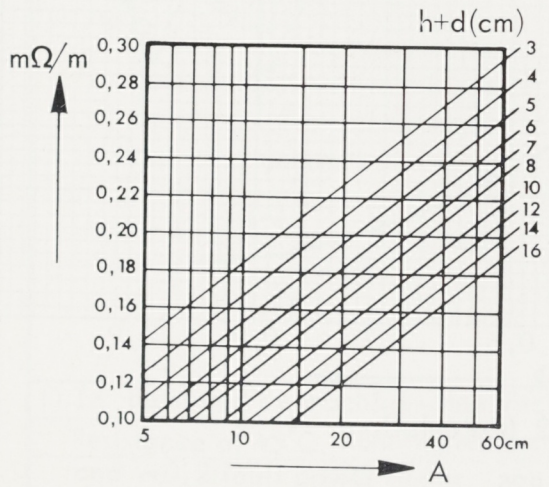
Table no 1 Conductor resistances and reactances ship cables 1)

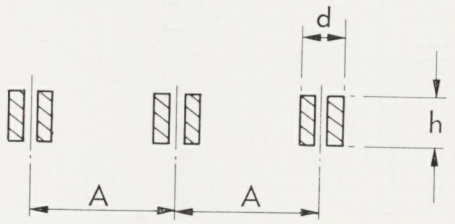
| Cross section | | r | x(50 cps) | x(60 cps) |
|---|---|---|---|---|
| mm² | | mΩ/m | mΩ/m | mΩ/m |
| | 3/,029 | 14,650 | 0,138 | 0,166 |
| 1,5 | | 12,96 | 0,1 | 0,12 |
| | 3/,036 | 9,419 | 0,126 | 0,151 |
| 2,5 | | 7,59 | 0,123 | 0,147 |
| | 7/,029 | 6,264 | 0,120 | 0,144 |
| 4 | | 4,747 | 0,117 | 0,141 |
| | 7/,036 | 4,025 | 0,116 | 0,140 |
| 6 | | 3,00 | 0,113 | 0,135 |
| | 7/,044 | 2,695 | 0,110 | 0,132 |
| | 7/,052 | 1,929 | 0,104 | 0,125 |
| 10 | | 1,836 | 0,103 | 0,123 |
| | 7/,064 | 1,274 | 0,098 | 0,118 |
| 16 | | 1,19 | 0,096 | 0,115 |
| | 19/,044 | 0,9945 | 0,093 | 0,112 |
| 25 | | 0,747 | 0,091 | 0,109 |
| | 19/,052 | 0,7121 | 0,09 | 0,108 |
| 35 | | 0,543 | 0,088 | 0,105 |

| Cross section | | r | x(50 cps) | x(60 cps) |
|---|---|---|---|---|
| mm² | | mΩ/m | mΩ/m | mΩ/m |
| | 19/,064 | 0,4748 | 0,087 | 0,105 |
| 50 | | 0,394 | 0,085 | 0,102 |
| 60 | | 0,3214 | 0,083 | 0,097 |
| | 19/,083 | 0,2893 | 0,082 | 0,098 |
| 70 | | 0,2735 | 0,082 | 0,098 |
| 95 | | 0,216 | 0,081 | 0,097 |
| | 37/,072 | 0,1957 | 0,080 | 0,096 |
| 120 | | 0,166 | 0,080 | 0,096 |
| | 37/,083 | 0,1544 | 0,080 | 0,096 |
| 150 | | 0,1353 | 0,079 | 0,095 |
| | 37/,093 | 0,1248 | 0,079 | 0,095 |
| 185 | | 0,1087 | 0,078 | 0,094 |
| | 37/,103 | 0,1026 | 0,078 | 0,094 |
| 240 | | 0,085 | 0,077 | 0,093 |
| | 61/,093 | 0,07816 | 0,077 | 0,093 |
| 300 | | 0,071 | 0,077 | 0,093 |
| | 61/,103 | 0,06675 | 0,077 | 0,093 |

1) r = Resistance of A.C cables at 45°C
x = Reactance of multicore A.C cables

Table No 2 Conductor reactances of busbars at 50 cps
correction factor at 60 cps : 1,2

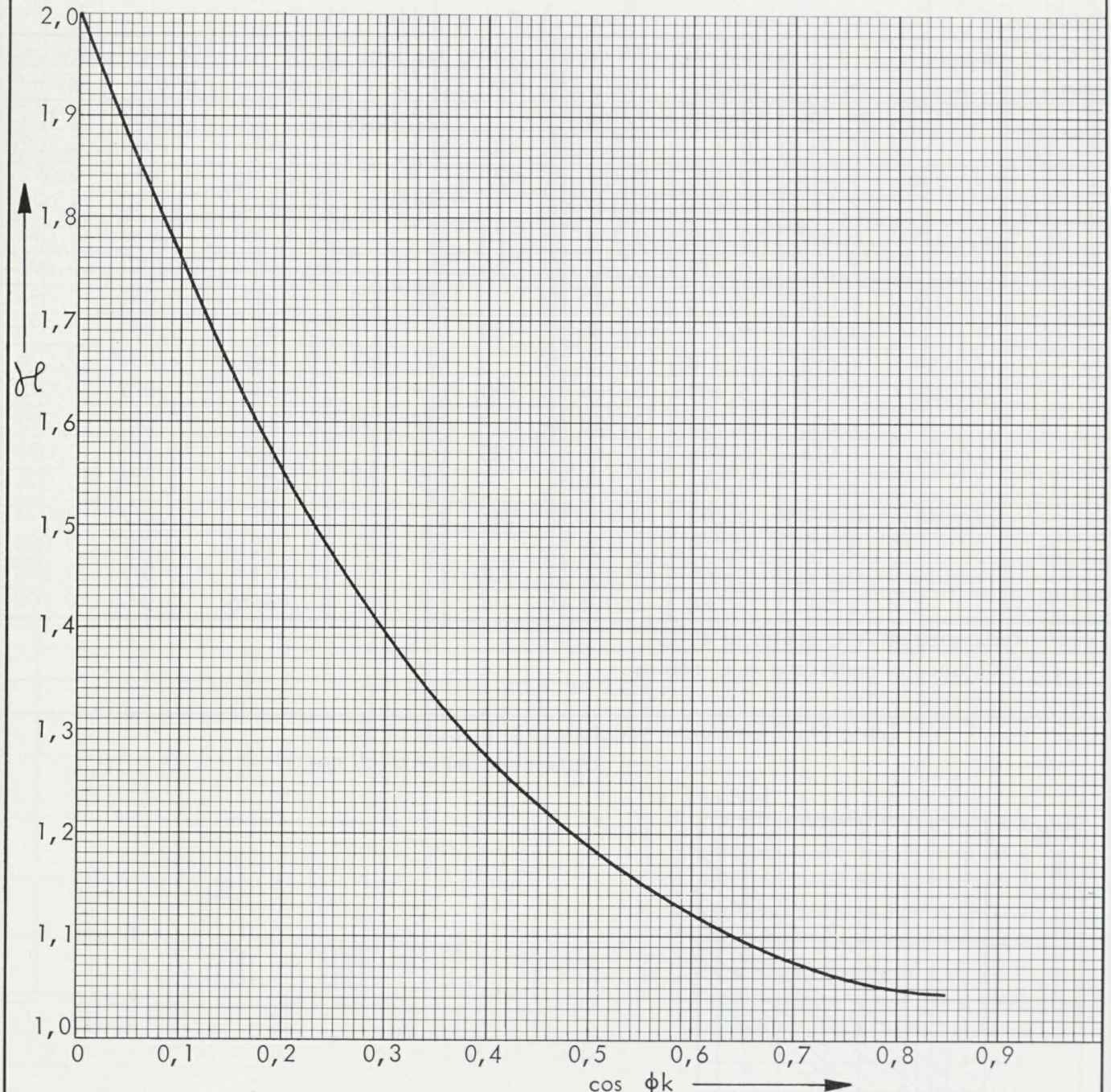



Sheet V

| | Page |
|---|---|
| A C short circuit calculation | |
| Data sheet 2 | |

Table No 3 Doubling factor $\varkappa = f(\cos \phi k)$




Determination of C: (Reduction factor)

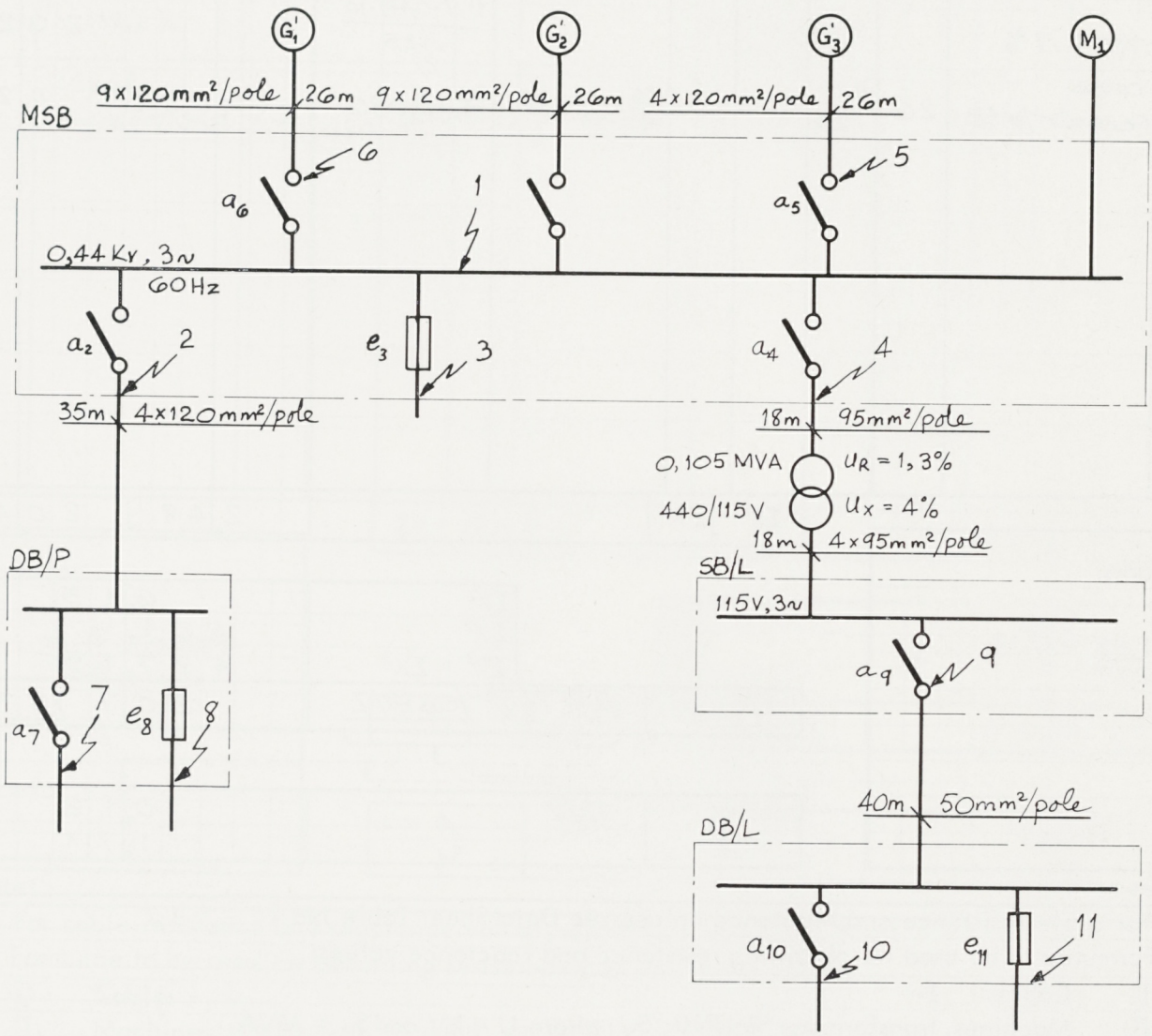
e g $\cos\phi = 0,4$ (Protective device)

and $\cos\phi_K = 0,2$ (Calculation)

$$C = \frac{1,28}{1,55} \quad 0,825$$

Sheet VI

| Short circuit A.C calculation | | | | Page 1 |
|---|---|---|---|---|
| Network-Diagram | | | | |
| Builder: XYZ | | Yard No 4711 | | |
| $S_N$ (MVA) | 1,125 | 1,125 | 0,6 | $\Sigma$ 1,125 |
| $J_N$ (kA) | 1,45 | 1,45 | 0,768 | $\Sigma$ 1,45 |
| R (mΩ) 1) | 2 | 2 | 3 | 6% |
| $X''_d$ (%) 1) | 11,7 | 11,7 | 15,2 | 33% |
| Number: | 1 | 1 | 1 | running motors |
| | | | | |




1) To be stated by machine-Manufacturer. Values per phase.
Resistance at 45°C. Running motors assessed on basis of 70% running generators, 3xFL current and ~0,2 fault power factor

Sheet 1b

Determination of resistances and reactances per phase for short circuit — Page 2

Point No

G1 and cable = G2 and cable

| Item | Designation | $l$ | $n/\square^2$ | $r$ 1) | $x$ 1) | R 2) | X 2) | R | X |
|---|---|---|---|---|---|---|---|---|---|
| | | m | mm² | mΩ/m | mΩ/m | mΩ | mΩ | mΩ | mΩ |
| 1 | Generator $S_N$ = 1,125 MVA | | | | | | | | |
| | U = 0,44 kV R = 2 mΩ | | | | | | | 2 | |
| | X = 11,7 % | | | | | | $\frac{11,7 \cdot 0,44^2 \cdot 10}{1,125}$ | | 2 0,2 |
| 2 | cable Generator/MSB | 26 | 9/120 | 0,166 | 0,096 | $\frac{26}{9} \cdot 0,166$ | $\frac{26}{9} \cdot 0,096$ | 0,48 | 0,28 |
| | | | | $\Sigma R + j\Sigma X$ | | | | 2,48 +j | 20,48 |

Remarks:

$\frac{2,48}{20,7} = 0,12$

| | | |
|---|---|---|
| $\Sigma R^2$ | | 6,15 |
| $\Sigma X^2$ | | 421, |
| $\Sigma R^2 + \Sigma X^2$ | | 427,15 |
| $Z\angle\varphi_{K\,3)}$ = | $\sqrt{\Sigma R^2 + \Sigma X^2}\ \angle\cos \Sigma R/Z$ | 20,7 ∠83 |
| $\cos \varphi_K$ = | $\Sigma R/Z$ | 0,12 |
| $\partial l$ 5) | | 1,71 |

Notes :

1) For cable resistance and reactance values, see Data Sheet Table No 1

2) Formulae to be used for obtaining resistance and reactance values;

I) Cables : $\frac{1}{n} \cdot r$

II) Machines, transformer; $\% \cdot U^2 \cdot 10 / S_N$ ; where U = kV and $S_N$ = MVA

III) Recalculation for other voltages ; $R_2 = R\,(U_2/U)^2$ ; $X_2 = X \cdot (U_2/U)^2$

3) $\varphi_K$ = Short circuit angle

4) For busbar resistance and reactance values , see Data sheet Table No 2

5) For doubling factor $\partial l$ see Data sheet, Table No 3

Sheet II

Determination of resistances and reactances per phase for short circuit — Page 3

Point No

Generator 3

| Item | Designation | l | n/□² | r 1) | x 1) | R 2) | X 2) | R | X |
|---|---|---|---|---|---|---|---|---|---|
| | | m | mm² | mΩ/m | mΩ/m | mΩ | mΩ | mΩ | mΩ |
| 1 | Generator $S_N$=0,6 MVA | | | | | | | | |
| | U=0,44 KV | | | | | | | 3 | |
| | R=3 mΩ | | | | | | | | |
| | x=15,2% | | | | | | $\frac{15,2 \cdot 0,44^2 \cdot 10}{0,6}$ | | 49,6 |
| 2 | Cable Generator/MSB | 26 | 4/120 | 0,166 | 0,096 | $\frac{26}{4} \cdot 0,166$ | $\frac{26}{4} \cdot 0,096$ | 1,08 | 0,63 |
| | | | | | | | | | |
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| | | | | | | | | | |
| | | | | | | | | | |
| | | | | ΣR + jΣX | | | | 4,08 +j | 50,23 |

Remarks:

$\frac{4,08}{50,4} = 0,081$

| | | |
|---|---|---|
| | $\Sigma R^2$ | 16,7 |
| | $\Sigma X^2$ | 2520, |
| | $\Sigma R^2 + \Sigma X^2$ | 2536, |
| $Z/\phi_{K\,3)}$ = | $\sqrt{\Sigma R^2 + \Sigma X^2}$ / $\cos \Sigma R/Z$ | 50,4 / 85,3 |
| $\cos \phi_K$ = | $\Sigma R/Z$ | 0,081 |
| $\partial\ell$ 5) | | 1,8 |

Notes :

1) For cable resistance and reactance values, see Data Sheet Table No 1

2) Formulae to be used for obtaining resistance and reactance values;

I) Cables : $\frac{1}{n} \cdot r$

II) Machines, transformer; $\%\cdot U^2 \cdot 10 / S_N$ ; where U = kV and $S_N$ = MVA

III) Recalculation for other voltages ; $R_2 = R\,(U_2/U)^2$ ; $X_2 = X \cdot (U_2/U)^2$

3) $\phi_K$ = Short circuit angle

4) For busbar resistance and reactance values , see Data sheet Table No 2

5) For doubling factor $\partial\ell$ see Data sheet, Table No 3

Sheet II

Determination of resistances and reactances per phase for short circuit — Page 4

Point No M 1

| Item | Designation | $l$ | $n/\square^2$ | $r$ 1) | $x$ 1) | R 2) | X 2) | R | X |
|---|---|---|---|---|---|---|---|---|---|
| | | m | $mm^2$ | $\frac{m\Omega}{m}$ | $\frac{m\Omega}{m}$ | $m\Omega$ | $m\Omega$ | $m\Omega$ | $m\Omega$ |
| 1 | Running motors $\Sigma S_N = 1{,}125$ MVA | | | | | | | | |
| | $U = 0{,}44$ kV $R = 6\%$ | | | | | $\frac{6 \cdot 0{,}44^2 \cdot 10}{1{,}125}$ | | 10,35 | |
| | $x = 33\%$ | | | | | | $\frac{33 \cdot 0{,}44^2 \cdot 10}{1{,}125}$ | | 57,5 |
| | | | | $\Sigma R + j\Sigma X$ | | | | 10,35 +j | 57,5 |

Remarks:

$\frac{10{,}35}{58{,}4} = 0{,}1775$

| | | |
|---|---|---|
| | $\Sigma R^2$ | 107, |
| | $\Sigma X^2$ | 3300, |
| | $\Sigma R^2 + \Sigma X^2$ | 3407, |
| $Z/\phi_K$ 3) = | $\sqrt{\Sigma R^2 + \Sigma X^2}$ / $\cos \Sigma R/Z$ | 58,4 / 79,8 |
| $\cos \phi_K$ = | $\Sigma R/Z$ | 0,178 |
| $\partial l$ 5) | | 1,6 |

Notes :

1) For cable resistance and reactance values, see Data Sheet Table No 1

2) Formulae to be used for obtaining resistance and reactance values;

I) Cables : $\frac{l}{n} \cdot r$

II) Machines, transformer; $\% \cdot U^2 \cdot 10 / S_N$ ; where U = kV and $S_N$ = MVA

III) Recalculation for other voltages ; $R_2 = R\,(U_2/U)^2$ ; $X_2 = X \cdot (U_2/U)^2$

3) $\phi_K$ = Short circuit angle

4) For busbar resistance and reactance values , see Data sheet Table No 2

5) For doubling factor $\partial l$ see Data sheet, Table No 3

Sheet II

Determination of resistances and reactances for short circuit point No ═══ for parallel operating machines and associated cables.

Generator (1) + (2) + (−) + (−) + Motor (−) + (−)

Page 5

| Item | | $Z/\phi_K$ mΩ/— | R mΩ | X mΩ |
|---|---|---|---|---|
| 1 | $Z_1$ = (from page 2) | 20,7 / 83 | 2,48 | 20,48 |
| 2 | $Z_2$ = (from page 2) | 20,7 / 83 | 2,48 | 20,48 |
| | | | ΣR | ΣX |
| | | | $\Sigma R^2$ | |
| | | | $\Sigma X^2$ | |
| | | | $\Sigma R^2 + \Sigma X^2$ | |
| 3 | $Z_1 + Z_2$ = $\sqrt{\Sigma R^2 + \Sigma X^2}$ $\tan \Sigma X/\Sigma R$ | | | |
| 4 | $Z/\phi_K$ = $\frac{Z_1 \cdot Z_2}{Z_1 + Z_2}$ | — / — = 1) | | |

| | $Z \cdot \cos\phi_K$ | $Z \cdot \sin\phi_K$ |
|---|---|---|
| $R + jX$ = | 1,24 +j | 10,24 |

Remarks :

$Z_1 = Z_2 \rightarrow Z = \frac{1}{2} \cdot Z_1$

$\varphi = \varphi_1$

$Z\phi_K$ = (from item 4) 10,3583

$\cos\phi_K = R/Z$ 0,121 / 1,71 2)

Notes

1) $\frac{a/\alpha \cdot b/\beta}{c/\gamma} = \frac{a \cdot b}{c} / \alpha + \beta - \gamma$

2) For doubling factor see Data Sheet table No 3

Sheet III

Determination of resistances and reactances for short circuit point No —— for parallel operating machines and associated cables.

Generator(−) + (−) + (3) + (−) + Motor (1) + ( )

Page 6

| Item | | $Z/\phi_K$ mΩ/ | R mΩ | X mΩ |
|---|---|---|---|---|
| 1 | $Z_1$ = (from page 3) | 50,4 /85,3 | 40,8 | 50,23 |
| 2 | $Z_2$ = (from page 4) | 58,4 /79,8 | 10,35 | 57,5 |
| | | ΣR ΣX | 14,43 | 107,73 |
| | | $\Sigma R^2$ | 208, | |
| | | $\Sigma X^2$ | 11450, | |
| | | $\Sigma R^2 + \Sigma X^2$ | 11658, | |
| 3 | $Z_1 + Z_2$ = $\sqrt{\Sigma R^2 + \Sigma X^2}$ $\tan \Sigma X/\Sigma R$ | | 108, | /82,4 |
| 4 | $Z/\phi_K$ = $\frac{Z_1 \cdot Z_2}{Z_1 + Z_2}$ | $\frac{50,4/85,3 \cdot 58,4/79,8}{108/82,4}$ = 1) | 272, | /82,7 |

| | $Z \cdot \cos\phi_K$ | $Z \cdot \sin\phi_K$ |
|---|---|---|
| $R + jX$ = | 34,5 + j | 26,9 |

| | | |
|---|---|---|
| $Z\phi_K$ = | (from item 4) | 272, /82,7 |
| $\cos\phi_K = R/Z$ | 0,127 | |
| 2) | 1,69 | |

Remarks :

$\frac{107,73}{14,43} = 7,47$

85,3
+ 79,8
165,1

− 82,4
82,7

Notes

1) $\frac{a/\alpha \cdot b/\beta}{c/\gamma} = \frac{a \cdot b}{c} /\alpha + \beta - \gamma$

2) For doubling factor see Data sheet table No 3

Sheet III

Determination of resistances and reactances for short circuit point No 1 for parallel operating machines and associated cables.

Page 7

Generator( ) + ( ) + ( ) + ( ) + Motor ( ) + ( )

| Item | | | Z/φK mΩ/ | R mΩ | X mΩ |
|---|---|---|---|---|---|
| 1 | $Z_1$ = | (from page 5) | 10,35 /83 | 1,24 | 10,24 |
| 2 | $Z_2$ = | (from page 6) | 27,2 /82,7 | 3,45 | 26,9 |
| | | | ΣR ΣX | 4,69 | 37,14 |
| | | | $\Sigma R^2$ | 22, | |
| | | | $\Sigma X^2$ | 1380, | |
| | | | $\Sigma R^2 + \Sigma X^2$ | 1402, | |
| 3 | $Z_1 + Z_2$ = | $\sqrt{\Sigma R^2 + \Sigma X^2}$ tan ΣX/ΣR | | 37,4 | /82,8 |
| 4 | $Z/\phi_K$ = | $\frac{Z_1 \cdot Z_2}{Z_1 + Z_2}$ | $\frac{10,35/83 \quad 27,2/82,7}{37,4/82,8}$ 1) = | 7,54 | /82,9 |

0,124 0,99

$Z \cdot \cos\phi_K$ | $Z \cdot \sin\phi_K$

$R + jX$ = 0,94 +j 7,46

$Z\phi_K$ = (from item 4) 7,54 /82,9

$\cos\phi_K = R/Z$ 0,124

$\partial\ell$ 2) 1,7

Remarks :

83
82,7
165,7
82,8
82,9

Notes

1) $\frac{a/\alpha \cdot b/\beta}{c/\gamma} = \frac{a \cdot b}{c} /\alpha + \beta - \gamma$

2) For doubling factor see Data Sheet table No 3

Sheet III

Determination of resistances and reactances for short circuit point No 6 for parallel operating machines and associated cables.

Page 8

Generator( ) + (2) + (3) + ( ) + Motor (1) + ( )

| Item | | | Z/φK<br>mΩ/ | R<br>mΩ | X<br>mΩ |
|---|---|---|---|---|---|
| 1 | $Z_1$ = | (from page 2) | 20,7 /83 | 2,48 | 20,48 |
| 2 | $Z_2$ = | (from page 6) | 27,2 /82,7 | 3,45 | 26,9 |
| | | | ΣR ΣX | 5,93 | 47,38 |
| | | | $\Sigma R^2$ | 35, | |
| | | | $\Sigma X^2$ | 2250, | |
| | | | $\Sigma R^2 + \Sigma X^2$ | 2285, | |
| 3 | $Z_1 + Z_2$ = | $\sqrt{\Sigma R^2 + \Sigma X^2}$ tan ΣX/ΣR | | 47,7 | /82,9 |
| 4 | Z/φK = | $\frac{Z_1 \cdot Z_2}{Z_1 + Z_2}$ | $\frac{20,7 /83 \quad 27,2 /82,7}{47,7 /82,9}$ 1) = | 118, | /82,8 |

0,125 | 0,99

| | Z · cos φK | Z · sin φK |
|---|---|---|
| R + jX = | 1,47 | +j 11,7 |

| | | |
|---|---|---|
| Zφ K = | (from item 4) | 118, /82,8 |
| cos φK = R/Z | 0,125 | |
| ∂l 2) | 1,7 | |

Remarks :

83
82,7
165,7
82,9
82,8

Notes

1) $\frac{a/\alpha \cdot b/\beta}{c/\gamma} = \frac{a \cdot b}{c} /\alpha + \beta - \gamma$

2) For doubling factor see Data Sheet table No 3

Sheet III

Determination of resistances and reactances for short circuit point No for parallel operating machines and associated cables.

Generator( 1 ) + ( 2 ) + ( ) + ( ) + Motor ( 1 ) + ( )

Page 9

| Item | | | $Z/\phi_K$ mΩ/ | R mΩ | X mΩ |
|---|---|---|---|---|---|
| 1 | $Z_1$ = | (from page 5) | 10,35 / 83 | 1,24 | 10,24 |
| 2 | $Z_2$ = | (from page 4) | 58,4 / 79,8 | 10,35 | 57,5 |
| | | | ΣR ΣX | 11,59 | 67,74 |
| | | | $\Sigma R^2$ | 134, | |
| | | | $\Sigma X^2$ | 4600, | |
| | | | $\Sigma R^2 + \Sigma X^2$ | 4734, | |
| 3 | $Z_1 + Z_2$ = | $\sqrt{\Sigma R^2 + \Sigma X^2}$ tan $\Sigma X/\Sigma R$ | | 68,6 | /80,3 |
| 4 | $Z/\phi_K$ = | $\frac{Z_1 \cdot Z_2}{Z_1 + Z_2}$ | $\frac{10,35/83 \quad 58,4/79,8}{68,6/80,3}$ 1) = | 8,8 | /82,5 |

0,13 0,99

| $Z \cdot \cos\phi_K$ | $Z \cdot \sin\phi_K$ |
|---|---|
| 1,14 +j | 8,7 |

$R + jX$ =

$Z\phi_K$ = (from item 4) 8,8 /82,5

$\cos\phi_K = R/Z$ 0,13

$\vartheta\ell$ 2) 1,69

Remarks :

83
79,8
162,8
80,3
82,5

Notes

1) $\frac{a/\alpha \cdot b/\beta}{c/\gamma} = \frac{a \cdot b}{c} / \alpha + \beta - \gamma$

2) For doubling factor see Data Sheet table No 3

Sheet III

Determination of resistances and reactances per phase for short circuit

Page 10

Point No 7 & 8

| Item | Designation | $l$ | $n / \square^2$ | $r$ 1) | $x$ 1) | R 2) | X 2) | R | X |
|---|---|---|---|---|---|---|---|---|---|
| | | m | $mm^2$ | $\frac{m\Omega}{m}$ | $\frac{m\Omega}{m}$ | $m\Omega$ | $m\Omega$ | $m\Omega$ | $m\Omega$ |
| 1 | from page 7 | | | | | | | 0,944 | 7,466 |
| 2 | Cable MSB / DB/P | 35 | 4 / 120 | 0,166 | 0,096 | $\frac{35}{4} \cdot 0{,}166$ | $\frac{35}{4} \cdot 0{,}096$ | 1,45 | 0,84 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | $\Sigma R + j\Sigma X$ | | | | 2,39 +j | 8,30 |

Remarks:

| | |
|---|---|
| $\Sigma R^2$ | 5,8 |
| $\Sigma X^2$ | 69, |
| $\Sigma R^2 + \Sigma X^2$ | 74,8 |
| $Z / \phi_K$ 3) = $\sqrt{\Sigma R^2 + \Sigma X^2}$ / $\cos \Sigma R/Z$ | 8,64 / 74 |
| $\cos \phi_K$ = $\Sigma R/Z$ | 0,277 |
| $\partial l$ 5) | 1,42 |

Notes :

1) For cable resistance and reactance values, see Data Sheet Table No 1

2) Formulae to be used for obtaining resistance and reactance values;

I) Cables : $\frac{1}{n} \cdot r$

II) Machines, transformer; $\% \cdot U^2 \cdot 10$ / where U = kV and $S_N$ = MVA

III) Recalculation for other voltages ; $R_2 = R\,(U_2/U)^2$ ; $X_2 = X \cdot (U_2/U)^2$

3) $\phi_K$ = Short circuit angle

4) For busbar resistance and reactance values , see Data sheet Table No 2

5) For doubling factor $\partial l$ see Data sheet, Table No 3

Sheet II

Determination of resistances and reactances per phase for short circuit

Point No 9



| Item | Designation | $l$ | $n/\square^2$ | $r$ 1) | $x$ 1) | R 2) | X 2) | R | X |
|---|---|---|---|---|---|---|---|---|---|
| | | m | mm² | mΩ/m | mΩ/m | mΩ | mΩ | mΩ | mΩ |
| 1 | from page 7 | | | | | | | 0,944 | 7,96 |
| 2 | Cable MSB/Transf. | 18 | 1/95 | 0,216 | 0,097 | $\frac{18}{1}\cdot 0{,}216$ | $\frac{18}{1}\cdot 0{,}097$ | 3,9 | 1,75 |
| 3 | $\Sigma R/\Sigma X$ | | | | | | | 4,84 | 9,21 |
| 4 | Recalculation from 440 to 115 V | | | | | $4{,}84\cdot(\frac{115}{440})^2$ | $9{,}21\cdot(\frac{115}{440})^2$ | 0,33 | 0,63 |
| 5 | Transformer $S_N = 0{,}105$ MVA | | | | | | | | |
| | $u_R = 1{,}3\%$ | | | | | $\frac{1{,}3\cdot 0{,}115^2\cdot 10}{0{,}105}$ | | 1,63 | |
| | $u_X = 4\%$ | | | | | | $\frac{4\cdot 0{,}115^2\cdot 10}{0{,}105}$ | | 5,04 |
| | Cable Transf./SB/L | 18 | 4/95 | 0,216 | 0,097 | $\frac{18}{4}\cdot 0{,}216$ | $\frac{18}{4}\cdot 0{,}097$ | 0,97 | 0,44 |
| | | | | | | | | | |
| | | | | $\Sigma R + j\Sigma X$ | | (Item 4 to 6) | | 2,93 +j | 6,11 |

Remarks:

| | |
|---|---|
| $\Sigma R^2$ | 8,6 |
| $\Sigma X^2$ | 37,4 |
| $\Sigma R^2 + \Sigma X^2$ | 46,0 |
| $Z/\phi_K$ 3) = $\sqrt{\Sigma R^2 + \Sigma X^2}$ / $\cos \Sigma R/Z$ | 6,78 / 64,4 |
| $\cos \phi_K$ = $\Sigma R/Z$ | 0,432 |
| $\partial l$ 5) | 1,25 |

Notes :

1) For cable resistance and reactance values, see Data Sheet Table No 1

2) Formulae to be used for obtaining resistance and reactance values;

I) Cables : $\frac{1}{n}\cdot r$

II) Machines, transformer; $\%\cdot U^2\cdot 10 / S_N$ ; where U = kV and $S_N$ = MVA

III) Recalculation for other voltages ; $R_2 = R\,(U_2/U)^2$ ; $X_2 = X\cdot(U_2/U)^2$

3) $\phi_K$ = Short circuit angle

4) For busbar resistance and reactance values , see Data sheet Table No 2

5) For doubling factor $\partial l$ see Data sheet, Table No 3

Sheet II

Determination of resistances and reactances per phase for short circuit

Point No. 10 and 11

Page 12

| Item | Designation | $l$ | $n/\square^2$ | $r$ 1) | $x$ 1) | R 2) | X 2) | R | X |
|---|---|---|---|---|---|---|---|---|---|
| | | m | $mm^2$ | $\frac{m\Omega}{m}$ | $\frac{m\Omega}{m}$ | $m\Omega$ | $m\Omega$ | $m\Omega$ | $m\Omega$ |
| 1 | from page 11 | | | | | | | 2,93 | 6,11 |
| 2 | Cable SB/L/DB/L | 40 | 1/50 | 0,394 | 0,102 | $\frac{40}{1} \cdot 0{,}394$ | $\frac{40}{1} \cdot 0{,}102$ | 15,8 | 4,08 |
| | | | | | | | | | |
| | | | | | | | | | |
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| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | $\Sigma R + j\Sigma X$ | | | | 18,73 +j | 10,19 |

Remarks:

| | | |
|---|---|---|
| | $\Sigma R^2$ | 351, |
| | $\Sigma X^2$ | 104, |
| | $\Sigma R^2 + \Sigma X^2$ | 455, |
| $Z/\phi_K$ 3) = | $\sqrt{\Sigma R^2 + \Sigma X^2}$ $/\cos \Sigma R/Z$ | 21,3 $/28{,}5$ |
| $\cos \phi_K$ = | $\Sigma R/Z$ | 0,88 |
| $\partial l$ 5) | | 1,04 |

Notes :

1) For cable resistance and reactance values, see Data Sheet Table No 1

2) Formulae to be used for obtaining resistance and reactance values;

I) Cables : $\frac{1}{n} \cdot r$

II) Machines, transformer; $\% \cdot U^2 \cdot 10 / S_N$ ; where U = kV and $S_N$ = MVA

III) Recalculation for other voltages ; $R_2 = R\ (U_2/U)^2$ ; $X_2 = X \cdot (U_2/U)^2$

3) $\phi_K$ = Short circuit angle

4) For busbar resistance and reactance values , see Data sheet Table No 2

5) For doubling factor $\partial l$ see Data sheet, Table No 3

Sheet II

# Summary

| Short circuit point | Calculation | | | | | | | Protective device | | | | | | | | Recalculated breaking capacity at calculated $\cos\phi_K$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Impedances from page | Z | $\varkappa$ | $\cos\phi_K$ | U System Voltage | $= \frac{1{,}05 \cdot U}{\sqrt{3} \cdot Z}$ 1) | $= \varkappa \cdot \sqrt{2} \cdot J_K''$ | Rating of fuse | Cut off current of fuse | Rated Voltage | Breaker / Fuse, Index | Maker and type | $\cos\phi$ | $J_K''$ | $J_S$ | 2) C | $= C \cdot J_K''$ |
| No | Page | mΩ | - | - | V | kA | kA | A | kA | V | - | | - | kA | kA | - | kA |
| 1 | 7 | 7,54 | 1,7 | 0,12 | 440 | 35,4 | 85 | — | — | — | — | — | — | — | — | — | — |
| 2 | 7 | | 〃 | | | | | — | — | 600 | $a_2$ | ABC | 0,15 | 42 | 96,5 | 0,96 | 40,3 |
| 3 | 7 | | 〃 | | | | | 200 | 18 | 500 | $e_3$ | DEF | — | 100 | — | — | — |
| 4 | 7 | | 〃 | | | | | — | — | 500 | $a_4$ | ABC | 0,4 | 60 | 110 | 0,74 | 44,4 |
| 5 | 9 | 8,8 | 1,69 | 0,13 | 440 | 30,4 | 72,8 | — | — | 500 | $a_5$ | 〃 | 0,4 | 50 | 88 | 0,76 | 38 |
| 6 | 8 | 11,8 | 1,7 | 0,13 | 440 | 22,6 | 54,3 | — | — | 500 | $a_6$ | 〃 | 0,15 | 42 | 100 | 0,97 | 40,7 |
| 7 | 10 | 8,64 | 1,42 | 0,277 | 440 | 27,1 | 54,6 | — | — | 500 | $a_7$ | 〃 | 0,4 | 50 | 88 | 0,9 | 45 |
| 8 | 10 | 8,64 | 1,42 | 0,277 | 440 | 27,1 | 54,6 | 100 | 10 | 600 | $e_8$ | DEF | — | 100 | — | — | — |
| 9 | 11 | 6,78 | 1,25 | 0,43 | 115 | 10,3 | 18,2 | — | — | 240 | $a_9$ | XYZ | 0,3 | 22 | 44 | — | — |
| 10 | 12 | 21,3 | 1,04 | 0,88 | 115 | 3,28 | 4,83 | — | — | 250 | $a_{10}$ | XYZ | 0,4 | 5 | 9 | — | — |
| 11 | 12 | 21,3 | 1,04 | 0,88 | 115 | 3,28 | 4,83 | 50 | 2,3 | 500 | $e_{11}$ | DEF | — | 100 | — | — | — |

1) U (V); Z (mΩ)

2) For determination of factor C, see data sheet, Table 3

Sheet IV

Date:

Signature:

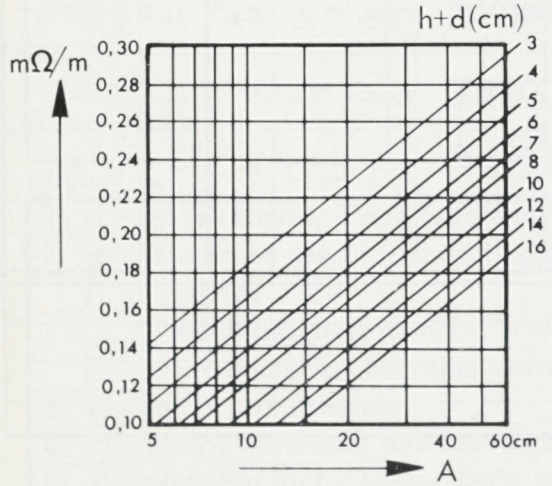
A.C short circuit calculation
Data Sheet 1

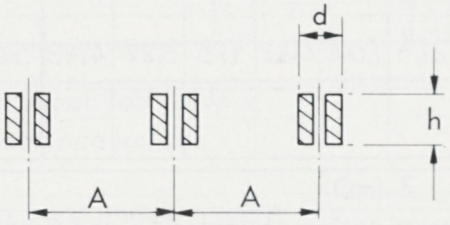
Table no 1 Conductor resistances and reactances ship cables 1)

| Cross section | | r | x(50 cps) | x(60 cps) | Cross section | | r | x(50 cps) | x(60 cps) |
|---|---|---|---|---|---|---|---|---|---|
| mm² | | mΩ/m | mΩ/m | mΩ/m | mm² | | mΩ/m | mΩ/m | mΩ/m |
| | 3/,029 | 14,650 | 0,138 | 0,166 | | 19/,064 | 0,4748 | 0,087 | 0,105 |
| 1,5 | | 12,96 | 0,1 | 0,12 | 50 | | 0,394 | 0,085 | 0,102 |
| | 3/,036 | 9,419 | 0,126 | 0,151 | 60 | | 0,3214 | 0,083 | 0,097 |
| 2,5 | | 7,59 | 0,123 | 0,147 | | 19/,083 | 0,2893 | 0,082 | 0,098 |
| | 7/,029 | 6,264 | 0,120 | 0,144 | 70 | | 0,2735 | 0,082 | 0,098 |
| 4 | | 4,747 | 0,117 | 0,141 | 95 | | 0,216 | 0,081 | 0,097 |
| | 7/,036 | 4,025 | 0,116 | 0,140 | | 37/,072 | 0,1957 | 0,080 | 0,096 |
| 6 | | 3,00 | 0,113 | 0,135 | 120 | | 0,166 | 0,080 | 0,096 |
| | 7/,044 | 2,695 | 0,110 | 0,132 | | 37/,083 | 0,1544 | 0,080 | 0,096 |
| | 7/,052 | 1,929 | 0,104 | 0,125 | 150 | | 0,1353 | 0,079 | 0,095 |
| 10 | | 1,836 | 0,103 | 0,123 | | 37/,093 | 0,1248 | 0,079 | 0,095 |
| | 7/,064 | 1,274 | 0,098 | 0,118 | 185 | | 0,1087 | 0,078 | 0,094 |
| 16 | | 1,19 | 0,096 | 0,115 | | 37/,103 | 0,1026 | 0,078 | 0,094 |
| | 19/,044 | 0,9945 | 0,093 | 0,112 | 240 | | 0,085 | 0,077 | 0,093 |
| 25 | | 0,747 | 0,091 | 0,109 | | 61/,093 | 0,07816 | 0,077 | 0,093 |
| | 19/,052 | 0,7121 | 0,09 | 0,108 | 300 | | 0,071 | 0,077 | 0,093 |
| 35 | | 0,543 | 0,088 | 0,105 | | 61/,103 | 0,06675 | 0,077 | 0,093 |

1) r = Resistance of AC cables at 45°C
x = Reactance of multicore AC cables

Table No 2 Conductor reactances of busbars at 50 cps
correction factor at 60 cps : 1,2



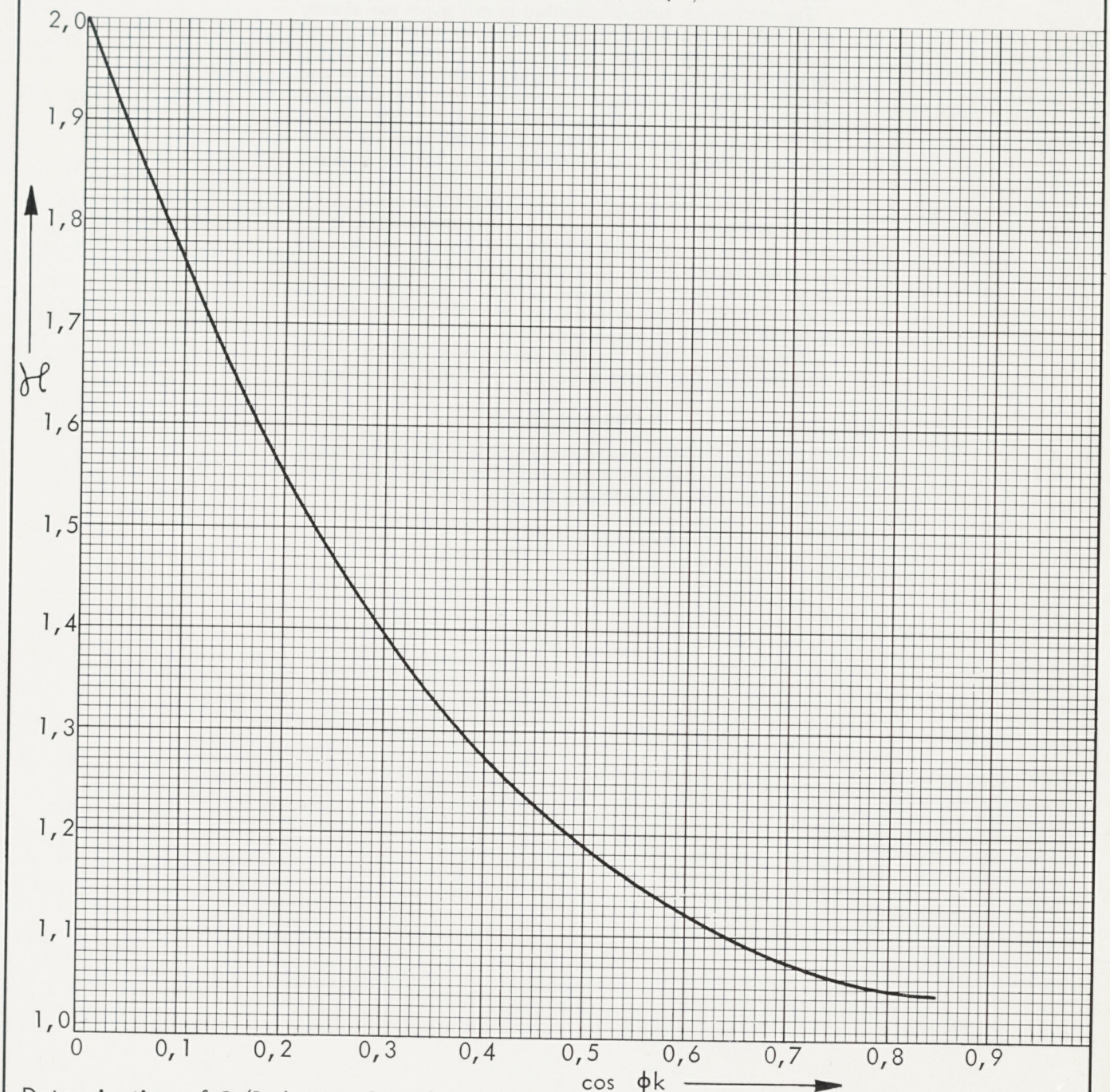




Sheet V

A C short circuit calculation

Data sheet 2

Table No 3 Doubling factor $\varkappa = f(\cos \phi k)$




Determination of C: (Reduction factor)

e g $\cos\phi = 0,4$ (Protective device)

and $\cos\phi_k = 0,2$ (Calculation)

$C = \frac{1,28}{1,55}$ 0,825

Sheet VI

## 5. Conclusions

The fault currents calculated by this method will generally be higher than those to be expected in practice because certain impedances have been assumed to be zero. This is not, however, a disadvantage since it provides the calculations with a built-in safety factor and immediately spot-lights border line cases. These can then be given special attention if necessary.

The calculation method described in this paper has already been used by Shipbuilders and Contractors who have found them straightforward and easy to apply. It has reduced the time spent by the Authors on checking such calculations and also the delays in subsequently dealing with the associated plans submitted for approval. It also quickly throws out the power factor of the fault which is, of course, essential for an accurate assessment of the protective devices for the proposed duty.

These power factors can be of the order 0,1 to 0,2 so that it is very desirable for the devices to be type tested at these levels since there is no guarantee that they will operate satisfactorily at power factors lower than those certified. The conversion factor C has been used by the Authors as an approximation but, as already stated, it should be used with caution and also with the approval of the manufacturers.

The summary sheet has been prepared so that the results may be easily transferred to or form part of the F.E. Report.


## Acknowledgment

The Authors wish to express their grateful thanks to Messrs. BICC for the conductor resistance and reactance values of the ship cables shown in the table on Sheet V.

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# BUCKLING AS A MODE OF FAILURE IN SHIP STRUCTURES

## PART I

J. I. Mathewson and A. C. Viner

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# BUCKLING AS A MODE OF FAILURE IN SHIP STRUCTURES—PART I

by J. I. MATHEWSON and A. C. VINER

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## 1.0 INTRODUCTION

The assessment of satisfactory standards of strength for ships is by tradition primarily concerned with the determination of stresses in the structure based upon the assumption that stable equilibrium exists between the internal and external forces. This is to say the equilibrium is such that within the elastic limit of the material any slight change in the loading produces a corresponding proportionate increase or decrease in the stresses or distortions of the system. Hence adherence to a certain limiting design stress ($\sigma_{AD}$) as a fraction of the yield stress of the material implies the assurance of elastic behaviour and the degree of safety of the structure.

The buckling phenomenon presents an entirely new aspect—the investigation of the potential unstable equilibrium between the external loading and the internal response of the structure. This condition is characterised by disproportionately large increases in deformations, and consequently stresses, resulting from very small increases in load. In consequence, buckling failures are normally sudden and can be catastrophic.

The instability condition occurs in structural members which are subjected to compressive loads, and in which at least one of the superficial dimensions is small relative to the others. The condition is a function of both the geometry of the component and the material properties, and therefore does not occur at one particular stress value for any given material, but may occur anywhere in the entire stress range provided the geometrical conditions are appropriate.

The factor of safety against buckling denoted by $\lambda$ may be expressed as follows:—

$$\lambda = \frac{\sigma_{CR}}{\sigma_{AD}}$$

where $\sigma_{CR}$ = critical buckling stress (to be defined later)
and $\sigma_{AD}$ = applied design stress

The object of this paper is two-fold:—

(a) To provide the plan approval Surveyor with sufficient insight into the problem to enable him to assess by calculation the probability of buckling for each component of ship structure in order that corrective measures may be incorporated in the design, and

(b) to illustrate the principals of the phenomenon in sufficient depth to allow the Surveyor engaged in survey to correctly identify a type of buckling failure and consequently recommend the most efficient repair.

In consequence this paper represents a collection of the results of the theory of buckling relevant to ship structural members presented in a manner which makes it suitable for practical application.

## 2.0 SUMMARY OF BUCKLING THEORY

The history of the development of a satisfactory buckling theory is marked by dissension between learned parties and more often a general lack of agreement between theory and experiment or practice. This situation can be traced to two main factors, one being a lack of basic understanding of the problem as a stability problem which persisted until the publication of Euler's work in 1759. The full value of this work, however, was not appreciated until it was extended beyond the elastic range by Engesser in 1895, and confirmed experimentally by Von Karman in 1908.

The second significant feature is the sensitivity of the theory to (a) very small eccentricities in application of the load, or (b) initial imperfections of the structure. This is in direct contrast to the elementary theory of bending where small changes in the positions of the loads have negligible effect on the stresses in the beams, and similarly slight deviations from the assumed initial straight form of the beam may also be neglected without invalidating the analysis.

Whilst theories have been developed to take account of such eccentricities of either loading or geometry, these are of limited practical value since a suitable standard of eccentricity to be found in ship structures has yet to be established. Not surprisingly, therefore, many of the practical solutions offered may be regarded as qualitative rather than quantitative. In such situations the factors of safety will tend to be higher than those used in elastic analysis, but since direct compression members such as pillars, etc., represent a relatively small proportion of the total steelweight of the structure this can be tolerated, whilst in the case of plating, by designing to the critical elastic buckling stress, there is implied a further reserve of post buckling strength which allows the adoption

of a lower factor of safety in some instances, an aspect to be dealt with in detail later.

## 3.0 FLEXURAL BUCKLING OF COLUMNS

### 3.1 The Euler Critical Load for a Concentrically Loaded Pin-Jointed Column.

The structural member shown in Fig. 1 is loaded both by an axial compressive force P and a lateral load Q. Such a member is known as a beam column. Under the assumption of small deflections y, the differential equation of the elastic curve of the deflected beam/column is:—

$$EI\frac{d^2y}{dx^2} = -\frac{Q_x}{2} - Py$$

Whence the maximum deflection $\delta$ at $\frac{l}{2}$ is given by:—

$$\delta = \frac{Ql^3}{48\,EI}\,\frac{3\,(\tan U - U)}{U^3} \qquad \text{Eq. 1}$$

where $U = \frac{l}{2}\sqrt{\frac{P}{EI}}$

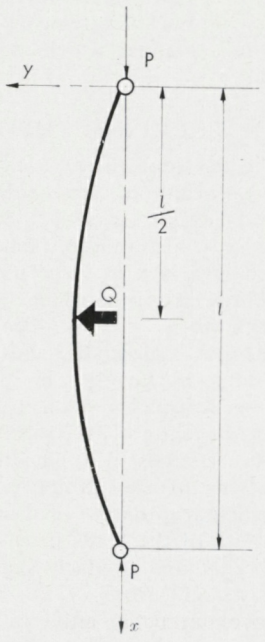



FIG. 1

The first factor on the right-hand side of equation (1) represents the deflection which is obtained by elementary beam theory if only the lateral load Q is acting. The system is in equilibrium. When the axial force P is small the value of U is also small, and the second factor approaches unity. However, as P increases the second factor also increases and approaches infinity as U approaches the value $\pi/2$. The second factor is known as the amplification factor and is

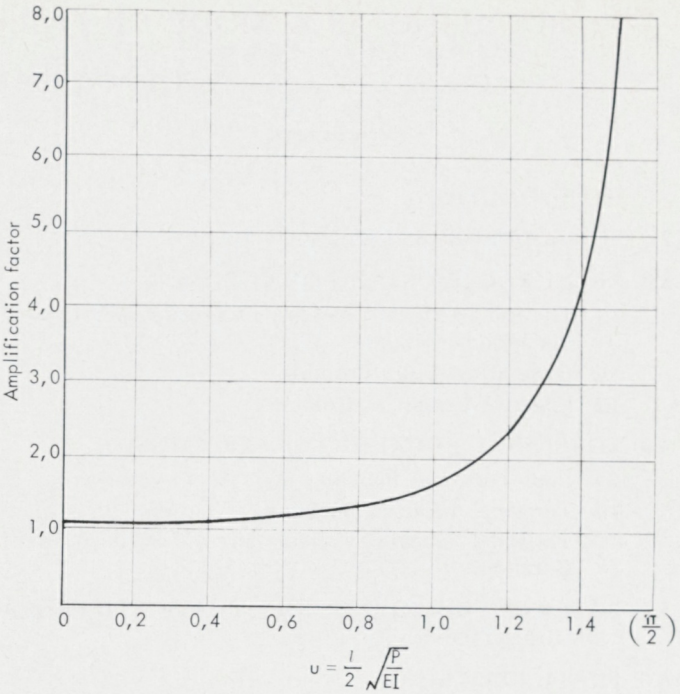



FIG. 2

Amplification Factor.

plotted in Fig. 2. It is evident that the deflection at the mid-length of the column approaches infinity when:—

$$\frac{l}{2}\sqrt{\frac{P}{EI}} = \frac{\pi}{2}$$

$$\text{whence } P_E = \frac{\pi^2\,EI}{l^2} \qquad \text{Eq. 2}$$

where $P_E$ is known as the Euler critical buckling load,

$$\text{or } \sigma_E = \frac{\pi^2\,E}{(l/r)^2} \qquad \text{Eq. 3}$$

where $\sigma_E$ = average critical buckling stress $= \frac{P_E}{A}$

A = cross-sectional area of column

I = inertia

r = radius of gyration $= \sqrt{\frac{I}{A}}$

$\frac{l}{r}$ = slenderness ratio

It may be noted that the Euler buckling load is independent of the magnitude of the lateral load. It is, therefore, applicable to the common case of a pillar with no lateral loading.

### 3.2 Generalised Euler Formula

The Euler formula as derived above is only valid within the elastic limit of the material. When yielding occurs in part of the column the buckling stress is considerably reduced. In order to extend the validity of the Euler formula over the entire working range, Engesser (Ref. 1) recommended replacing E by the tangent modulus, $E_t$, which is the slope of the stress-strain curve for the material in question. In the elastic range $E_t$ is identical to E, but as the yield stress is

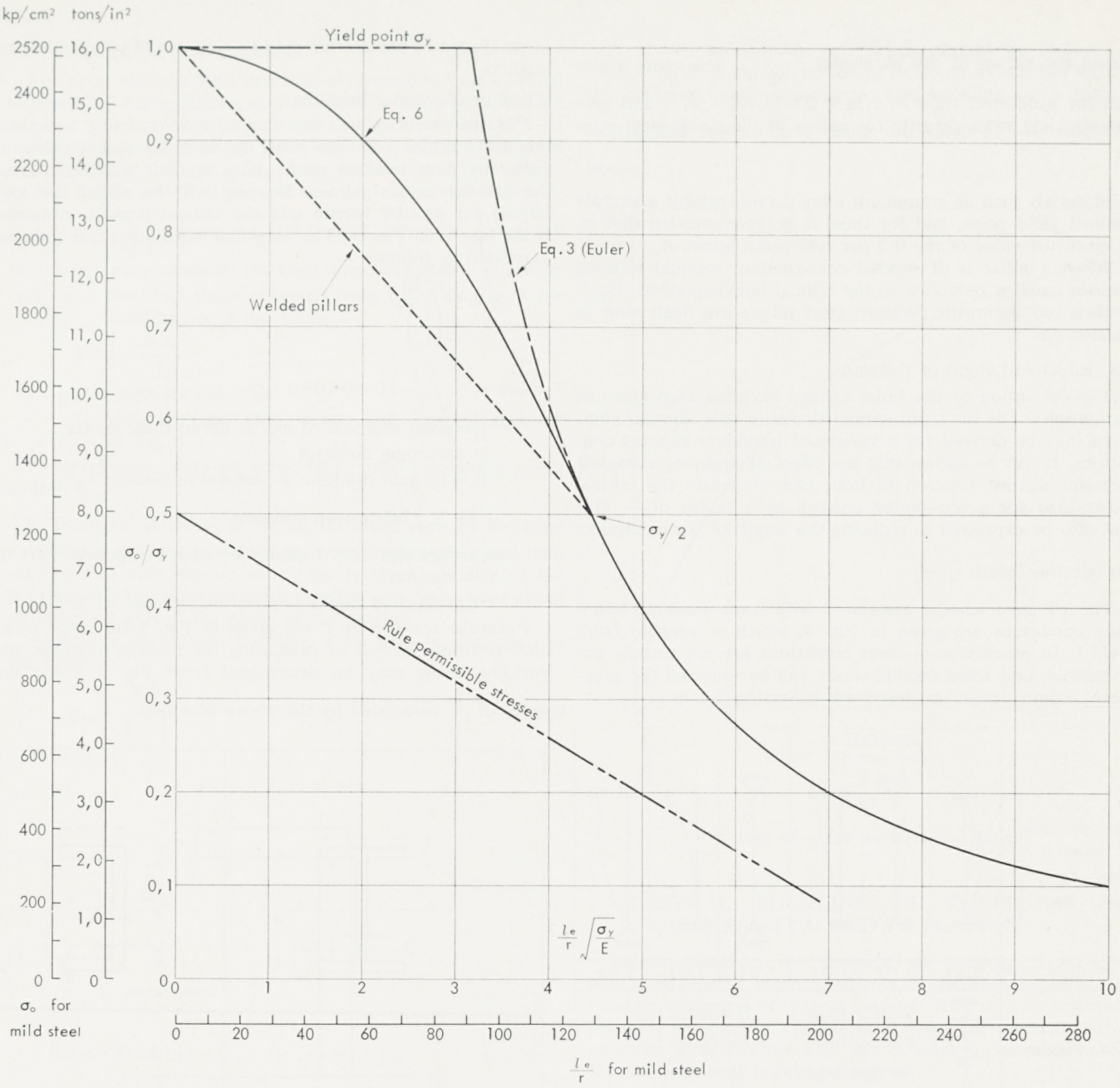



FIG. 3

Column strength curves.

approached $E_t$ reduces and tends to zero. Hence the actual buckling load becomes:—

$$P_o = \frac{\pi^2 E_t I}{l^2} \qquad \text{Eq. 4}$$

$$\text{or } \sigma_o = \frac{\pi^2 E_t}{(l_e/r)^2} \qquad \text{Eq. 5}$$

where $E_t = \frac{\triangle\sigma}{\triangle\varepsilon}$

$l_e$ = effective length (*see* Section 3.3).

The exact shape of the stress-strain curve is usually not known at the design stage, and it is more convenient to employ an empirical expression for $E_t$ in the inelastic range. One such formulation by Bleich (Ref. 2), applicable for stresses above half yield, leads to:—

$$\sigma_o = \sigma_y \left[1 - 4\frac{\sigma_y}{\pi^2 E}\left(\frac{l_e}{r}\right)^2\right] \text{ for } \sigma_E > 0.5\,\sigma_y$$

$$\sigma_o = \sigma_E \text{ for } \sigma_E \leqslant 0.5\,\sigma_y \qquad \text{Eq. 6}$$

where $\sigma_y$ = lower yield stress.

Eq. 6 is plotted in Fig. 3. The inner scales of Fig. 3 are applicable to all materials, and hence the value of $\frac{\sigma_o}{\sigma_y}$ may be

found for values of the parameter $\frac{l_e}{r}\sqrt{\frac{\sigma_y}{E}}$. The outer scales are for mild steel ($\sigma_y$=16 t/in.², E=13,400 t/in.²) and give the buckling stress directly for values of the slenderness ratio $\frac{l_e}{r}$.

Materials such as aluminium alloy do not exhibit a sharply defined yield point, and for these it is recommended that $\sigma_y$ is given the value of the 0·2 per cent proof stress, $\sigma_p$.

When a pillar is of welded construction, residual welding stresses cause a reduction in the critical buckling stress. Eq. 6 is then too optimistic. Welded steel pillars are dealt with in Section 8.2.

### 3.3 Effective Length of Columns

The derivation of the Euler critical buckling load given in paragraph 3.1 is for a pin-jointed structure only. Similar solutions may be derived for a variety of boundary support conditions. It can be shown that the effect of applying complete restraint against rotation at both ends increases the critical Euler load for a pin-jointed column by a factor of 4. This can also be expressed as reducing the length of the column to an effective length $l_e=\frac{l}{2}$.

The effective lengths associated with some classical boundary conditions are given in Fig. 4, which is adapted from Ref. 3. In practice such ideal conditions are not usually encountered, and some modifications will be required for practical column design, as described in Section 8.4.

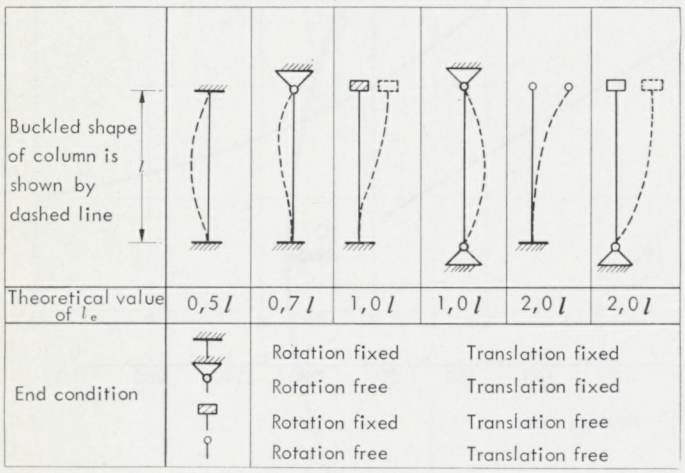



FIG. 4

Effective length of columns with various end conditions.

## 4.0 TORSIONAL BUCKLING OF COLUMNS

The Euler buckling load for columns is derived on the assumption that failure occurs by bending. For some types of section the buckling mode may be torsional or it may involve a combination of torsion and bending, i.e. torsional-flexural buckling. Closed sections, such as tubular or box-section pillars, are strong in torsion and torsional buckling need not be considered. Ordinary angles and T-sections are particularly susceptible to torsional buckling, and should therefore be avoided as struts or pillars in ship structures, except in the context dealt with later. The buckling stress for other types of open section may be estimated by the following method.

### 4.1 Pure Torsional Buckling

For open sections with two axes of symmetry (e.g. I-section) the shear centre coincides with the centroid and buckling is either by pure bending or by pure torsion, whichever gives the smaller critical stress. Bending will be about the axis having the smaller inertia and the critical stress is obtained from Eq. 6 or Fig. 3. The torsional buckling stress may be expressed as follows:—

$$\sigma_t=\frac{\pi^2 E_t}{\left(\frac{l_e}{r_t}\right)^2} \qquad \text{Eq. 7}$$

where $r_t=\sqrt{\frac{1}{I_p}(\Gamma+0{\cdot}039\ J\ l_e^2)}$

$I_p$ = polar moment of inertia about shear centre

$\Gamma$ = warping constant

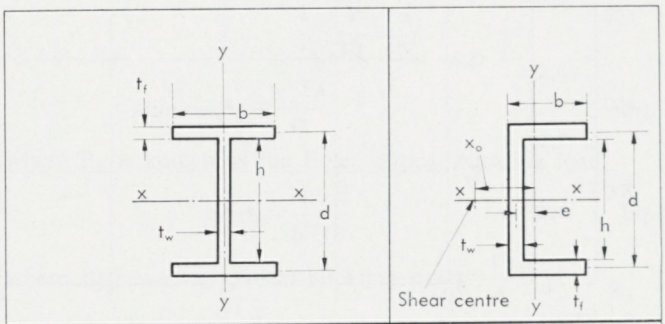
$E_t$ = tangent modulus as defined in Section 3.2.

$J=\Sigma\frac{1}{3}bt^3$ torsion constant

b, t = breadth and thickness of each component part of section

$l_e$ = effective length as given in Sections 3.3 & 8.4.

Formulæ for $I_p$ and $\Gamma$ are given in Fig. 5 for some common sections. Instead of evaluating the tangent modulus, the buckling stress may be determined from Fig. 3, using the value of $\frac{l_e}{r_t}$ calculated by the above formulæ.




| | | |
|---|---|---|
| J | $\frac{1}{3}\left(2b.\ t_f^3+h.\ t_w^3\right)$ | $\frac{1}{3}\left(2b.\ t_f^3+h.\ t_w^3\right)$ |
| $I_p$ | $I_x+I_y$ | $I_x+I_y+A.x_o^2$ |
| $\Gamma$ | $\frac{d^2.I_y}{4}$ | $\frac{d^2}{4}\left[I_y+e^2.A\left(1-\frac{d^2.A}{4.I_x}\right)\right]$ |
| $x_o$ | 0 | $e\left(1+\frac{d^2.A}{4.I_x}\right)$ |

A = total area of section

FIG. 5

Torsional properties of open sections.

4.2 Torsional-Flexural Buckling

For open sections with one axis of symmetry (e.g. channel section), this being defined as the x-axis, buckling occurs either by pure bending about the y-axis or by a combination of torsion and bending about the x-axis. The critical stress for bending about the y-axis, $\sigma_{oy}$, may be estimated from Eq. 6 or Fig. 3. The torsional-flexural buckling stress is given by:—

$$\sigma_{tf}=\frac{1}{2k}\left[\sigma_t+\sigma_{ox}-\sqrt{(\sigma_t+\sigma_{ox})^2-4k\sigma_t\sigma_{ox}}\right] \quad \text{Eq. 8}$$

where $\sigma_t$ = pure torsional buckling stress calculated as above.

$\sigma_{ox}$ = buckling stress obtained from Eq. 6 or Fig. 3 for bending about the x-axis.

$$k=1-\frac{A x_o^2}{I_p}$$

A = cross-section area

$x_o$ = distance from shear centre and centroid as given in Fig. 5.

Comprehensive data on torsional-flexural buckling is given in Ref. 4.

4.3 Torsional Buckling about an Enforced Axis of Rotation

Where a stiffener is welded to a continuous plate and then subjected to compressive stress, the torsional rigidity of the stiffener will be increased since rotation can only occur about an enforced axis in the plane of the plating.

As before the critical buckling stress may be expressed in the form:—

$$\sigma_{te}=\frac{\pi^2 E_t}{\left(\frac{l_e}{r_{te}}\right)^2} \quad \text{Eq. 9}$$

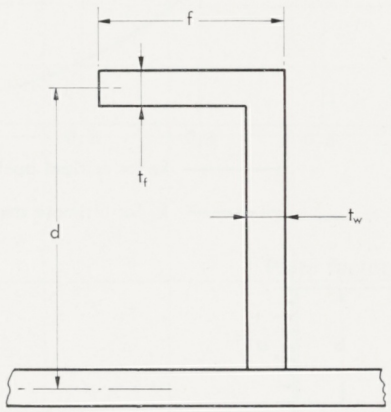



FIG. 6

where $r_{te}=\sqrt{\frac{1}{I_p}(\eta I_f d^2+0{\cdot}039 J l_e^2)}$

$I_p=A_f d^2+\frac{1}{3}t_w d^3+I_f$

$A_f$ = flange area = $f.t_f$

$I_f$ = flange inertia = $\frac{1}{12}f^3.t_f$

$\eta$ = 1 for symmetrical flange or face bar

$\eta$ taken from Fig. 7 for unsymmetrical flange

$E_t$ = tangent modulus as defined in Section 3.2.

A contribution from the plating should be included in estimating J. $l_e$ should normally be taken as the full span of the stiffener between supports. The buckling stress may be determined from Fig. 3 using the value of $\frac{l_e}{r_{te}}$ calculated above.

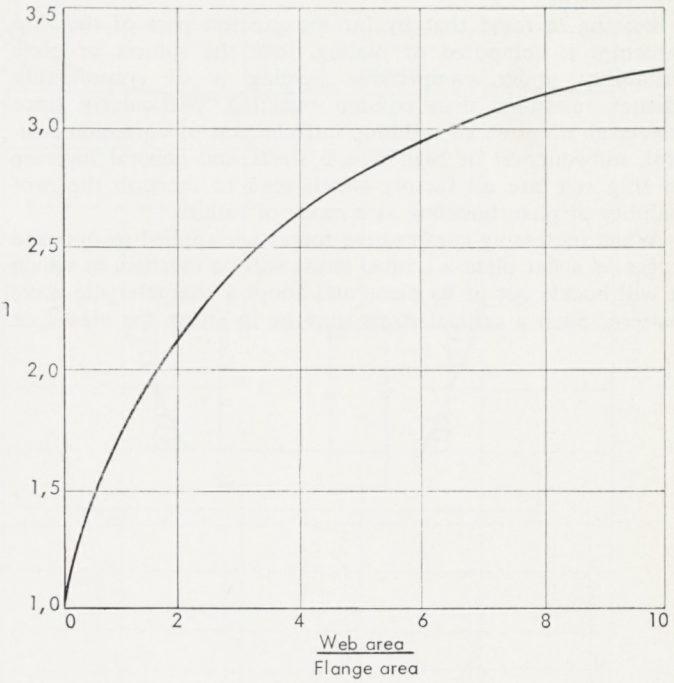



FIG. 7

Values of $\eta$ for asymmetric flange.

5.0 LATERAL BUCKLING OF STIFFENERS AND GIRDERS ATTACHED TO PLATING

Lateral buckling or "tripping" is a form of instability which may occur when a stiffener or girder is subject to end bending moments or lateral loading. It is usually sufficiently accurate to consider the flange or face bar, together with an effective portion of the web, as a column in compression. This leads to a critical buckling stress:—

$$\sigma_l=\frac{\pi^2 E_t}{\left(\frac{l_e}{r_l}\right)^2} \quad \text{Eq. 10}$$

where $r_l=\sqrt{\frac{\eta I_f}{A_f+\frac{1}{3}y_f t_w}}$

$y_f$ = distance from neutral axis to top of web

$t_w$ = web thickness (an increased "equivalent" thickness may be used where webs are stiffened longitudinally).

Other symbols as in Section 4.3.

To avoid the necessity of estimating the tangent modulus, $E_t$, the critical buckling stress may be determined from Fig. 3, with $\frac{l_e}{r_l}$ from above. The value of $l_e$ depends on the support

conditions of the flange or face bar. Where tripping brackets are fitted, $l_e$ should be taken as the distance between tripping brackets. For uniformly loaded members with no tripping brackets a value of $l_e = 0{\cdot}88\ l$ is recommended.

## 6.0 PLATE BUCKLING

### 6.1 General

Bearing in mind that by far the greatest part of the ship structure is composed of plating, then the subject of plate instability under compressive loading is of considerably greater relevance than column buckling, particularly since universal adoption of welding, introduction of corrosion control, introduction of high tensile steels and general increase in ship size are all factors which tend to increase the probability of plate buckling as a mode of failure.

When increasing compressive forces are applied to opposite edges of a flat plate a critical stress will be reached, at which it will buckle out of its plane and adopt a characteristic wave pattern. Such a critical stress may be in either the elastic or inelastic range and is similar in concept to the critical stress for the Euler column previously described.

### 6.2 Elastic Buckling

Since the problem is now two-dimensional, the aspect ratio of the plate is a significant parameter, and the solution for the critical compressive buckling stress $\sigma_c$, takes the characteristic form: —

$$\sigma_c = \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t}{s}\right)^2 k_c \qquad \text{Eq. 11}$$

where E = Young's modulus

$\nu$ = Poisson's ratio (0·3 for steel and aluminium alloy)

t = thickness of plating

s = length of shorter edge

$k_c$ = a factor depending on aspect ratio and boundary restraint

The plate factor, $k_c$, is plotted in Fig. 8 for simply supported plates in compression.

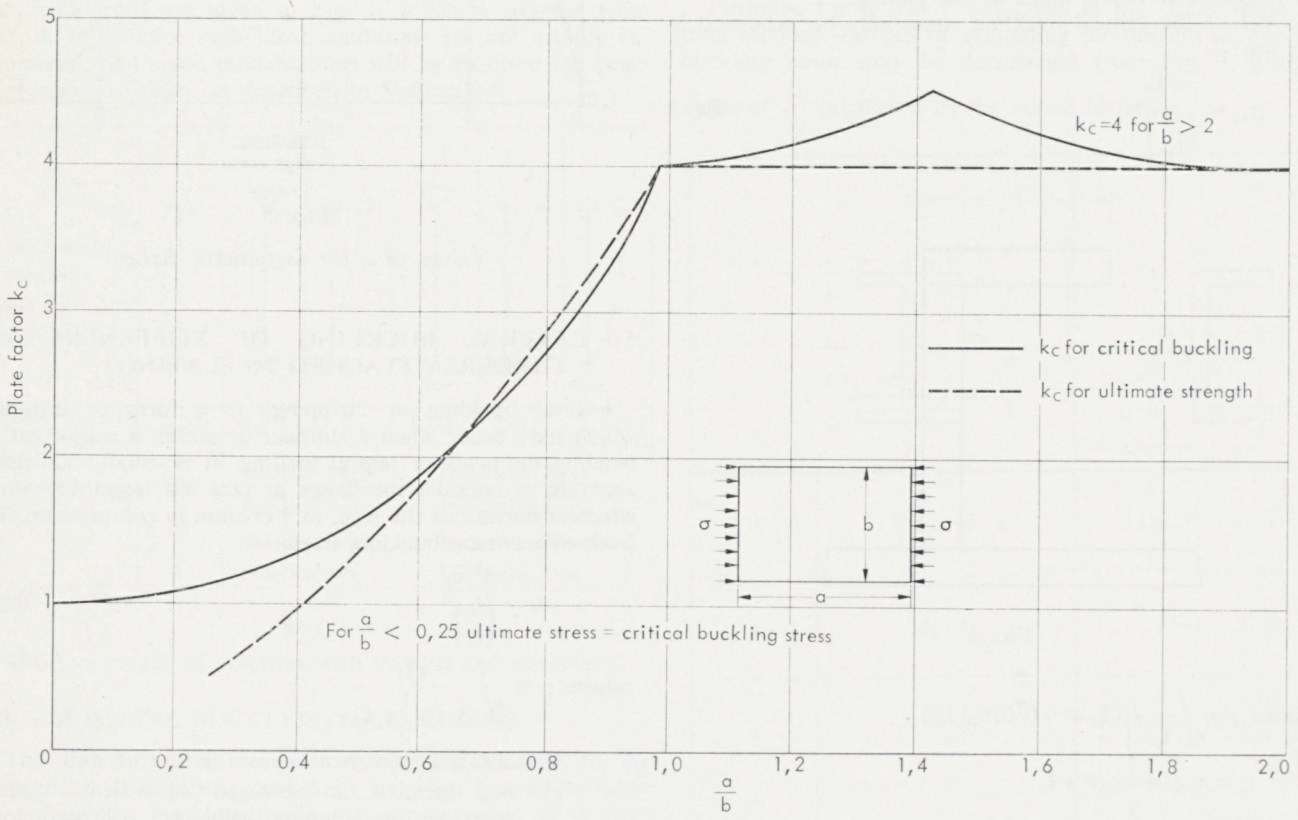



FIG. 8

Plate factors for simply supported plates in compression.

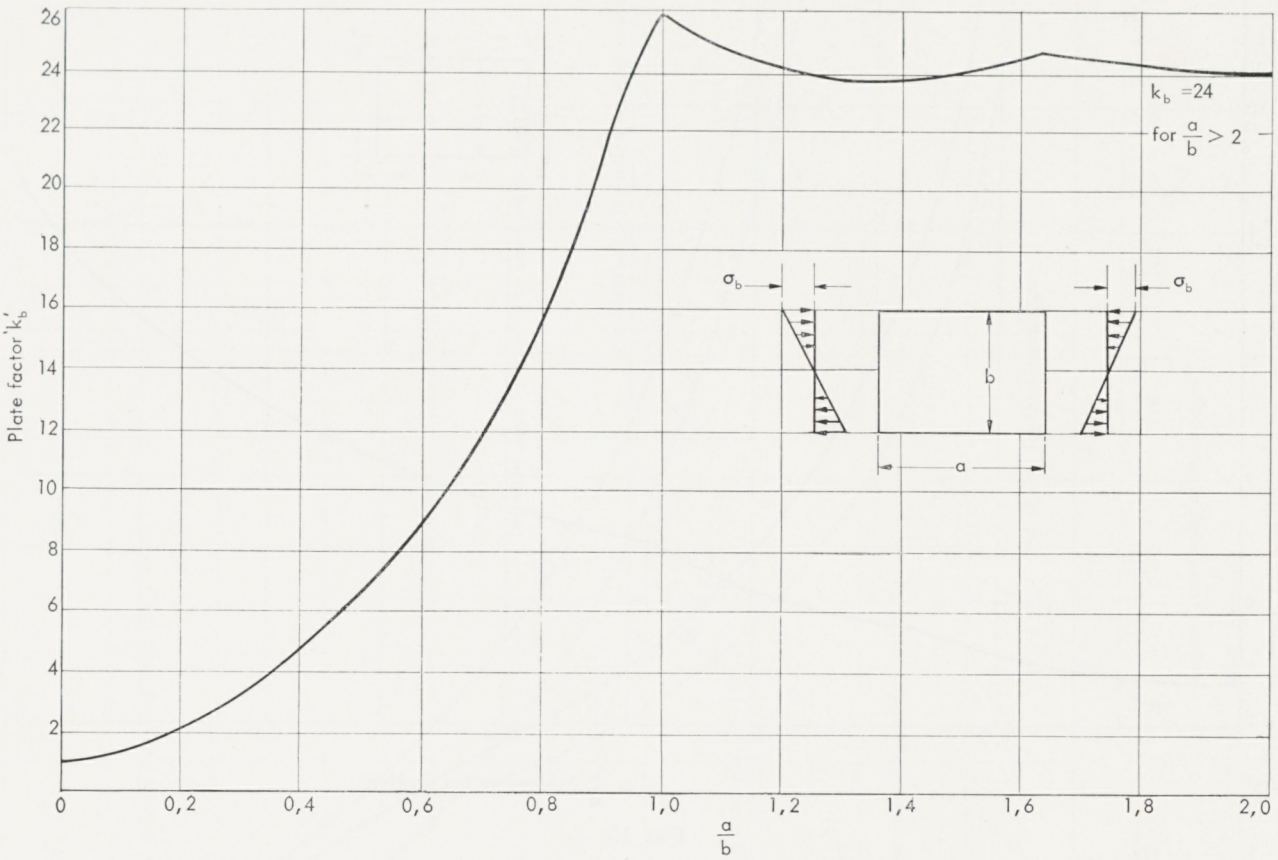



FIG. 9

Plate factors for simply supported plates in in-plane bending.

A similar equation is applicable to in-plane bending and the critical buckling stress for in-plane bending, $\sigma_{bc}$ becomes:—

$$\sigma_{bc} = \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t}{s}\right)^2 k_b \qquad \text{Eq. 12}$$

where the plate factor, $k_b$, is given in Fig. 9 for plate panels with simply supported edges.

Since shearing action produces a diagonal compression, buckling can also occur in plates subjected to shear stress and may be represented by the characteristic equation as before. The critical shear buckling stress is

$$\tau_c = \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t}{s}\right)^2 k_s \qquad \text{Eq. 13}$$

Values of $k_s$ for simply supported plates are given in Fig. 10.

In practical ship structures the panel under consideration is normally part of a continuous sheet where boundaries are enforced by stiffeners of relatively low torsional rigidity. In such circumstances, and for reasons connected with ultimate strength as discussed hereafter, boundary conditions for practical design purposes are normally taken as simply supported.

Where one long edge of a plate panel in compression is free (e.g. flat bar stiffeners or flanges of built sections) the plate factor may be taken as 0·43.

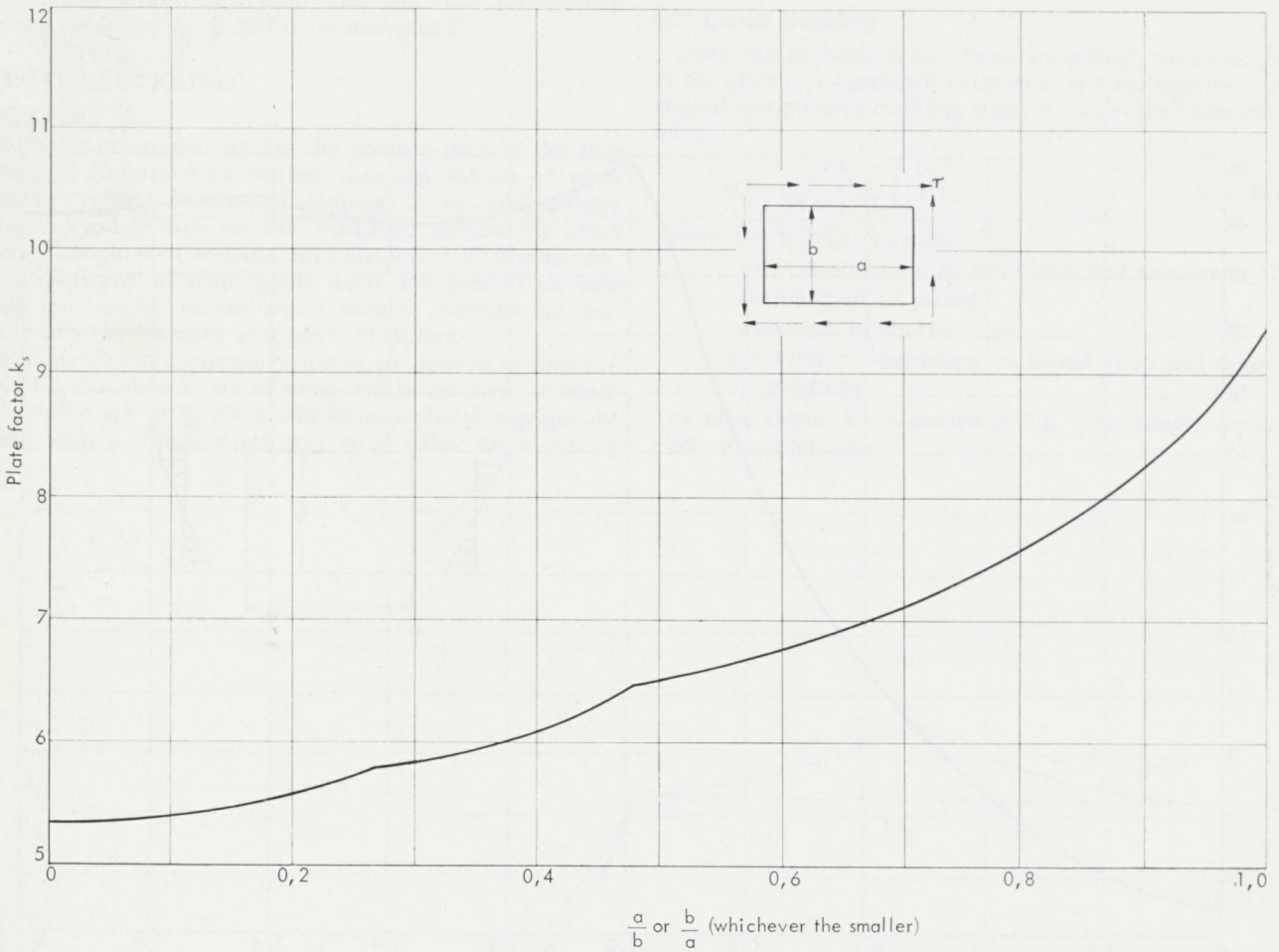



FIG. 10

Plate factors for simply supported plates in shear.

6.3 Inelastic Buckling

As in the case of column buckling, where the buckling stresses exceed the limit of proportionality, taken normally as 0·5 yield stress, then the actual critical stresses are less than those given by Eqs. 11, 12 and 13. According to the Johnson-Ostenfeld hypothesis (Ref. 5), the actual critical buckling stresses are:—

Compression

$$\left.\begin{aligned} \sigma_{co} &= \sigma_y \left(1-\frac{\sigma_y}{4\sigma_c}\right) && \text{for } \sigma_c > 0{\cdot}5\sigma_y \\ \sigma_{co} &= \sigma_c && \text{for } \sigma_c \leqslant 0{\cdot}5\sigma_y \end{aligned}\right\} \quad \text{Eq. 14}$$

In-plane bending

$$\left.\begin{aligned} \sigma_{bo} &= \sigma_y \left(1-\frac{\sigma_y}{4\sigma_{bc}}\right) && \text{for } \sigma_{bc} > 0{\cdot}5\sigma_y \\ \sigma_{bo} &= \sigma_{bc} && \text{for } \sigma_{bc} \leqslant 0{\cdot}5\sigma_y \end{aligned}\right\} \quad \text{Eq. 15}$$

Shear

$$\left.\begin{aligned} \tau_{co} &= \tau_y \left(1-\frac{\tau_y}{4\tau_c}\right) && \text{for } \tau_c > 0{\cdot}5\tau_y \\ \tau_{co} &= \tau_c && \text{for } \tau_c \leqslant 0{\cdot}5\tau_y \end{aligned}\right\} \quad \text{Eq. 16}$$

where the shear yield stress, $\tau_y = \dfrac{\sigma_y}{\sqrt{3}}$

By using the general base parameter $\dfrac{s}{t}\sqrt{\dfrac{4\sigma_y}{kE}}$ Eqs. 14, 15 and 16 may be represented by one curve, as given by the full line in Fig. 11. The plate factor, k, is given the appropriate value of $k_c$, $k_b$ or $k_s$ from Figs. 8–10, and the yield stress, $\sigma_y$, is replaced by $\tau_y$ for shear buckling. The inner scales of Fig. 11 are applicable to all materials and values of $\dfrac{\sigma_{co}}{\sigma_y}$, $\dfrac{\sigma_{bo}}{\sigma_y}$ and $\dfrac{\tau_{co}}{\tau_y}$ may be found for the appropriate values of the base parameter. The outer scales are for mild steel plates with the short edges in compression ($\sigma_y = 16$ t/in.², E = 13,400 t/in.², k = 4), and give critical buckling stresses directly for values of the breadth-thickness ratio, $\dfrac{s}{t}$

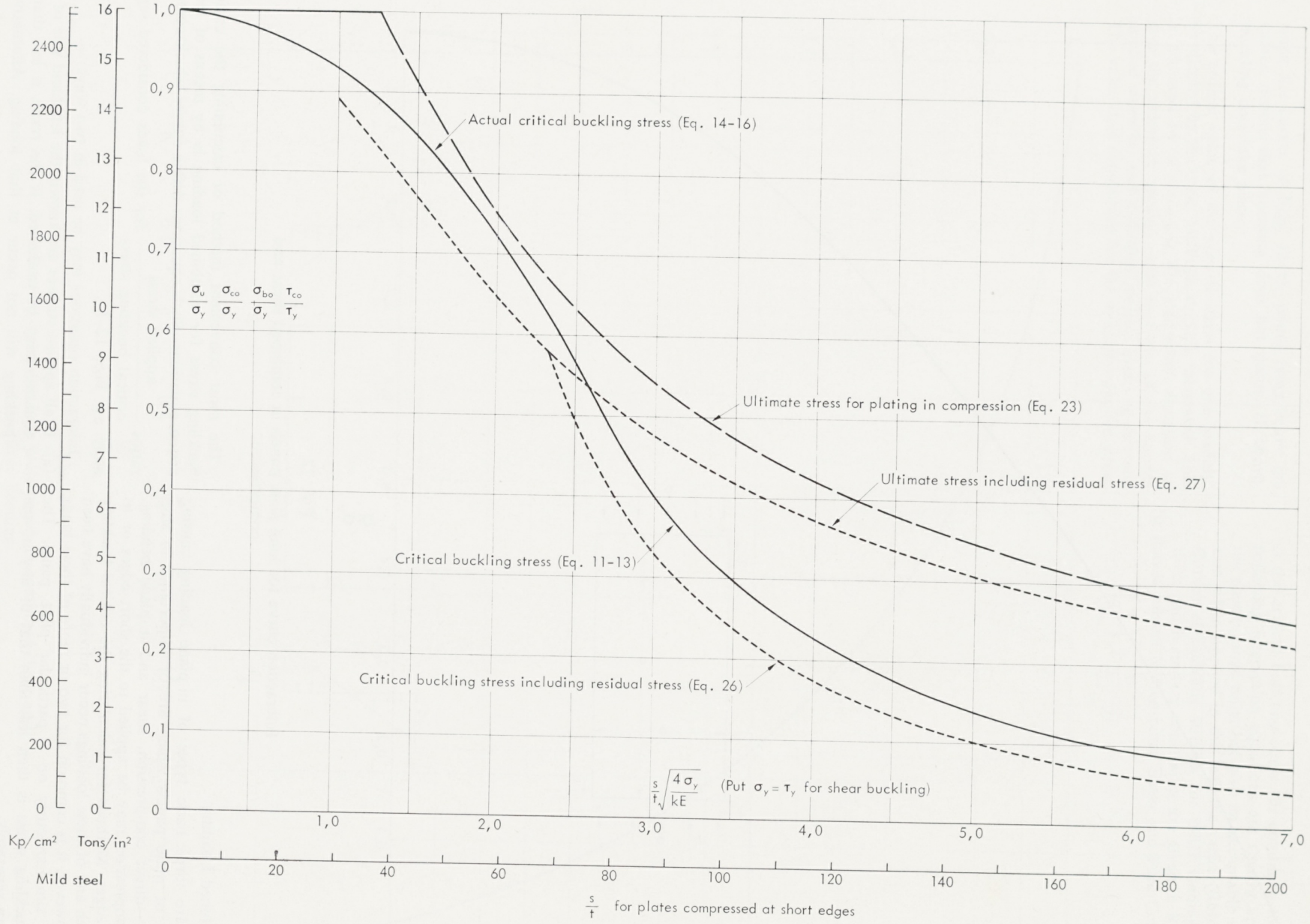



FIG. 11

Buckling strength of plating.

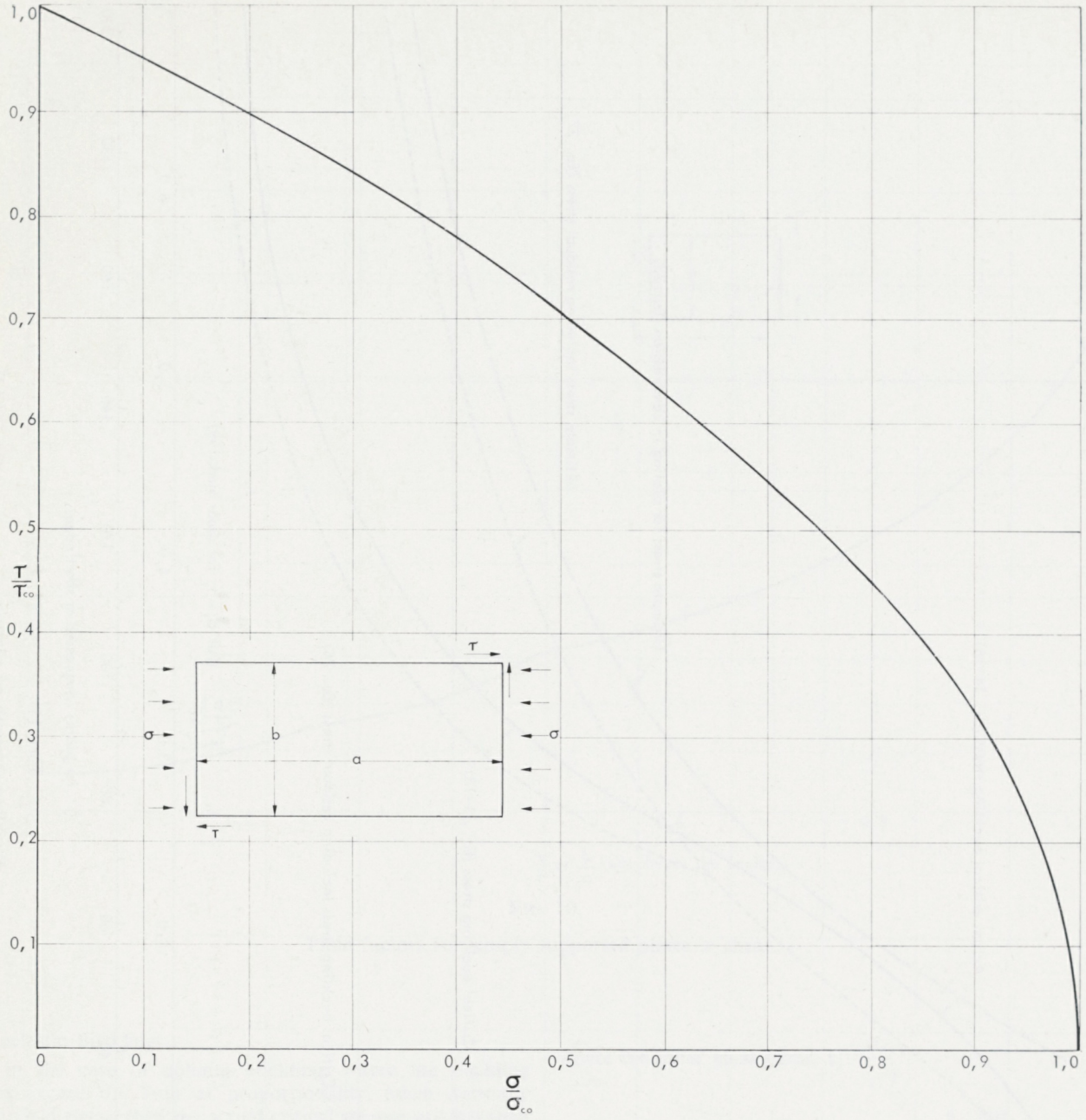



FIG. 12

Interaction curve for long plate panels in combined shear and compression.

6.4 Combined Loading

There are three basic types of in-plane loading causing instability of plate panels which are of importance in ship structures—direct compression, shear and in-plane bending. Direct compression may be applied to the short edges or to the long edges. Methods for calculating the critical buckling stress when any of these loadings occur individually have been given. However, it is common for two or more of these loads to occur simultaneously on a particular plate panel. The critical buckling stress is then less than that of any of the loads taken separately.

The most convenient method of calculating the critical buckling stress for combined loading is by means of interaction equations. Such equations define curves which connect ratios $\frac{\text{applied stress}}{\text{critical buckling stress}}$ for the loads considered separately, e.g. Figs. 12–15.

Interaction equations may be used in two ways:—

(a) If all applied stresses are known, the left-hand side of the equation may be evaluated. If the result is less than 1, buckling will not occur at that loading. Alternatively,

using the curves of Figs. 12–15, points lying below the curves denote that buckling does not occur. If above, buckling does take place.

(b) The critical value of the applied stress for one loading, as affected by the other loadings, may be calculated. This is achieved by re-arranging the interaction equation to give the unknown applied stress in terms of the known applied stress(es) and individual critical buckling stresses. The value thus determined for the unknown applied stress is the critical buckling stress for combined loading. The following interaction equations are strictly applicable in the elastic range only, but give an acceptable approximation when applied in the inelastic range (Refs. 6 and 7). Curves of buckling stresses for other loading combinations and boundary constraints are given in Ref. 8.

(i) Panels subject to Combined Shear and Pure Compression

$$\left(\frac{\tau}{\tau_{co}}\right)^2+\frac{\sigma}{\sigma_{co}}\leqslant 1 \qquad \text{Eq. 17}$$

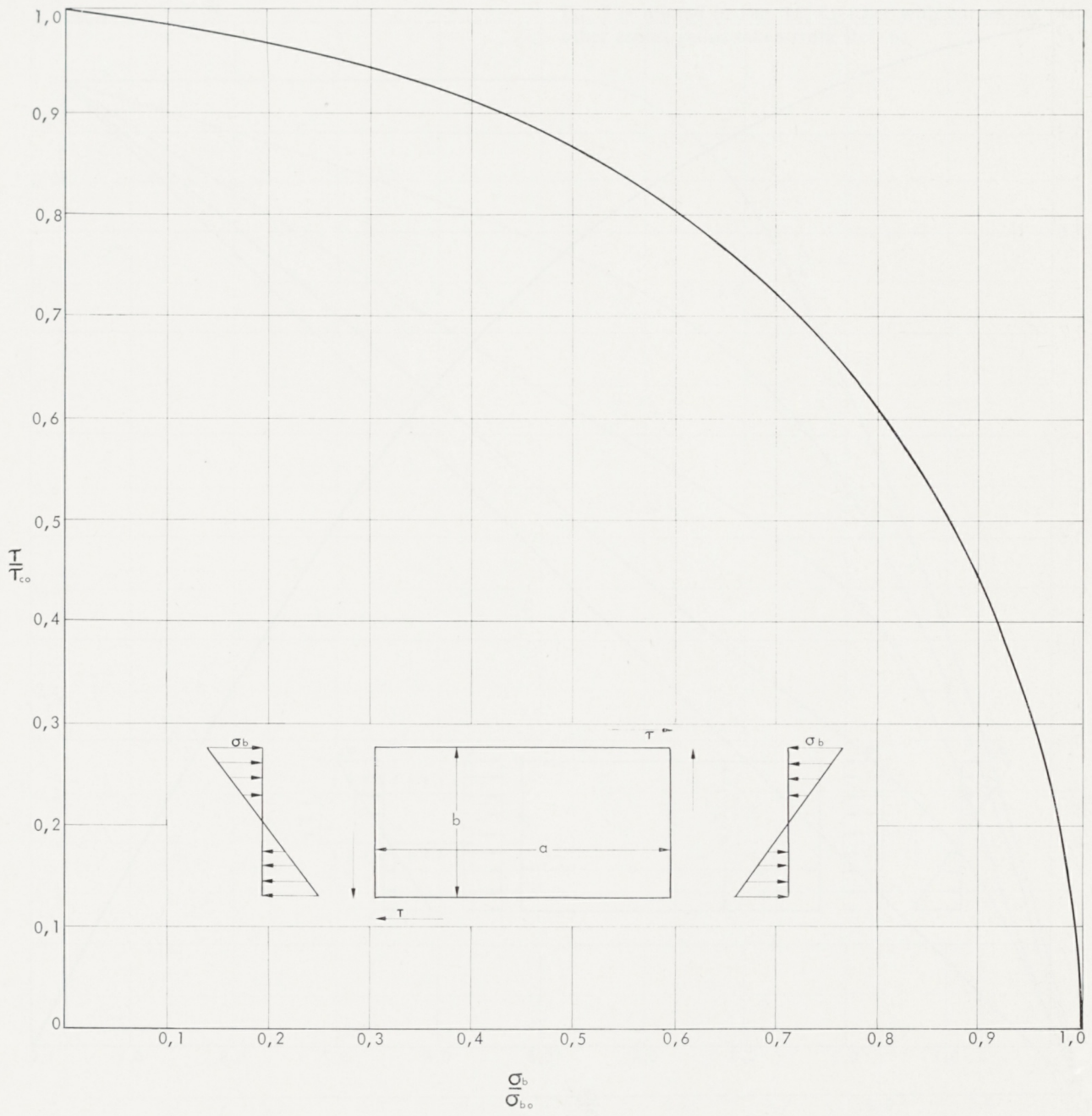



FIG. 13

Interaction curve for long plate panels in combined shear and in-plane bending.

where $\tau$ = applied shear stress

$\tau_{co}$ = critical shear stress when shear only as given by Eq. 16.

$\sigma$ = applied compressive stress

$\sigma_{co}$ = critical compressive stress when pure compression only as given by Eq. 14.

Eq. 17 is plotted in Fig. 12.

(ii) Panels subject to Combined Shear and In-Plane Bending

A very good approximation to the interaction curve is expressed by the circle: —

$$\left(\frac{\tau}{\tau_{co}}\right)^2 + \left(\frac{\sigma_b}{\sigma_{bo}}\right)^2 \leqslant 1 \qquad \text{Eq. 18}$$

where $\sigma_b$ = applied bending stress

$\sigma_{bo}$ = critical bending stress when pure bending only as given by Eq. 15.

Eq. 18 is plotted in Fig. 13.

(iii) Panels subject to Combined In-Plane Bending and Compression

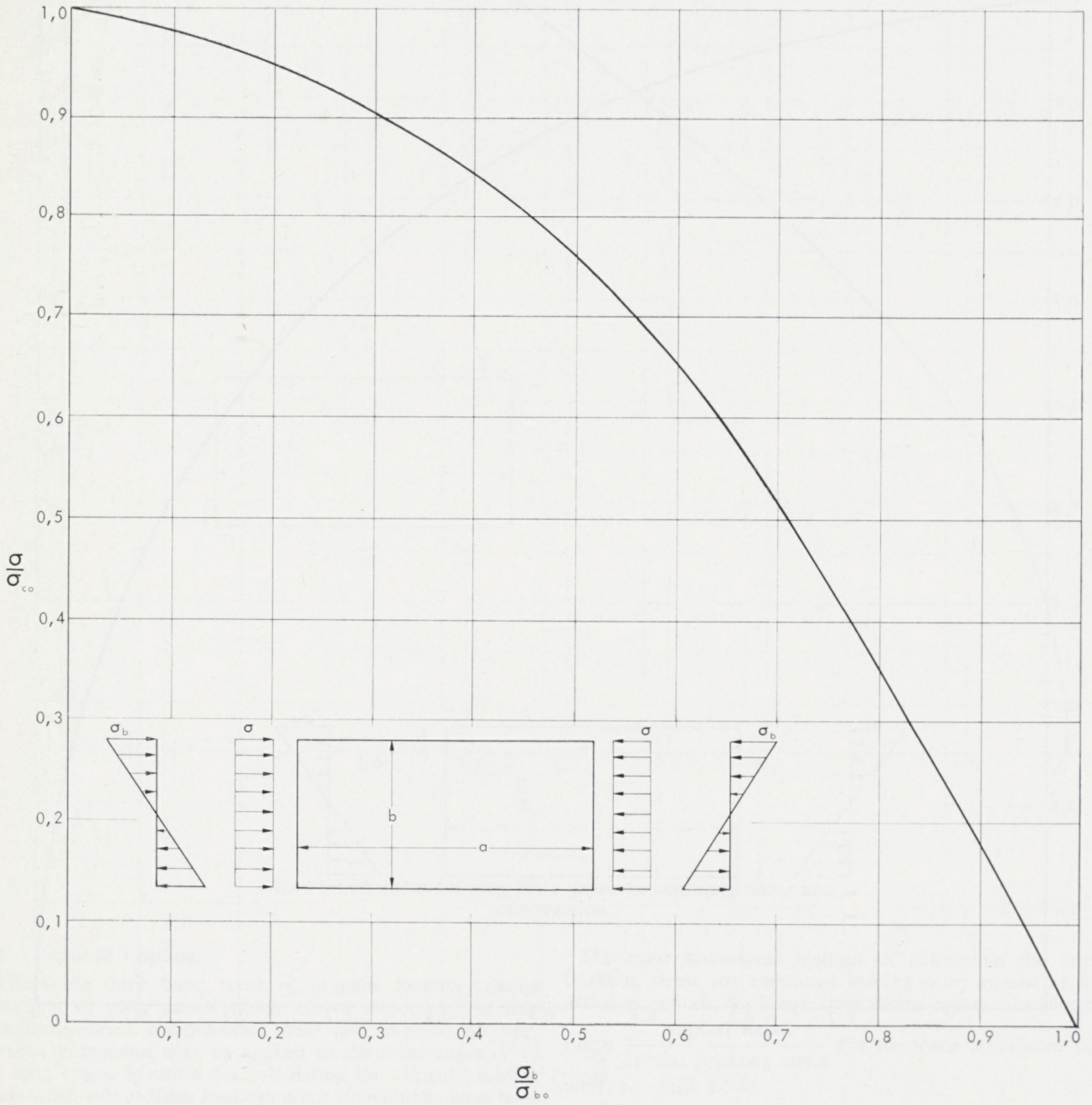



FIG. 14

Interaction curve for plate panels in combined in-plane bending and compression.

The interaction curve may be approximated by:—

$$\frac{\sigma}{\sigma_{co}}+\left(\frac{\sigma_b}{\sigma_{bo}}\right)^2 \leqslant 1 \qquad \text{Eq. 19}$$

Eq. 19 is plotted in Fig. 14. This interaction curve is applicable to the webs of stiffeners or girders where there is a linear stress distribution varying from $\sigma_1$ at the top to $\sigma_2$ at the bottom of a particular panel. The stress distribution is split into two component parts, as shown in Fig. 14, such that

$$\sigma=\frac{\sigma_1+\sigma_2}{2} \text{ and } \sigma_b=\frac{\sigma_1-\sigma_2}{2}$$

(iv) Panels subject to Compression in Two Orthogonal Directions

For square plate panels subject to applied stresses $\sigma_u$ and $\sigma_v$, in the orthogonal directions u and v respectively.

$$\frac{\sigma_u}{\sigma_{uo}}+\frac{\sigma_u}{\sigma_{vo}} \leqslant 1 \qquad \text{Eq. 20}$$

where $\sigma_{uo}$ $\sigma_{vo}$=critical compressive buckling stresses in u and v directions respectively, as given by Eq. 14.

Eq. 5 is plotted in Fig. 15, together with curves for plates of other aspect ratios taken from Ref. 6.

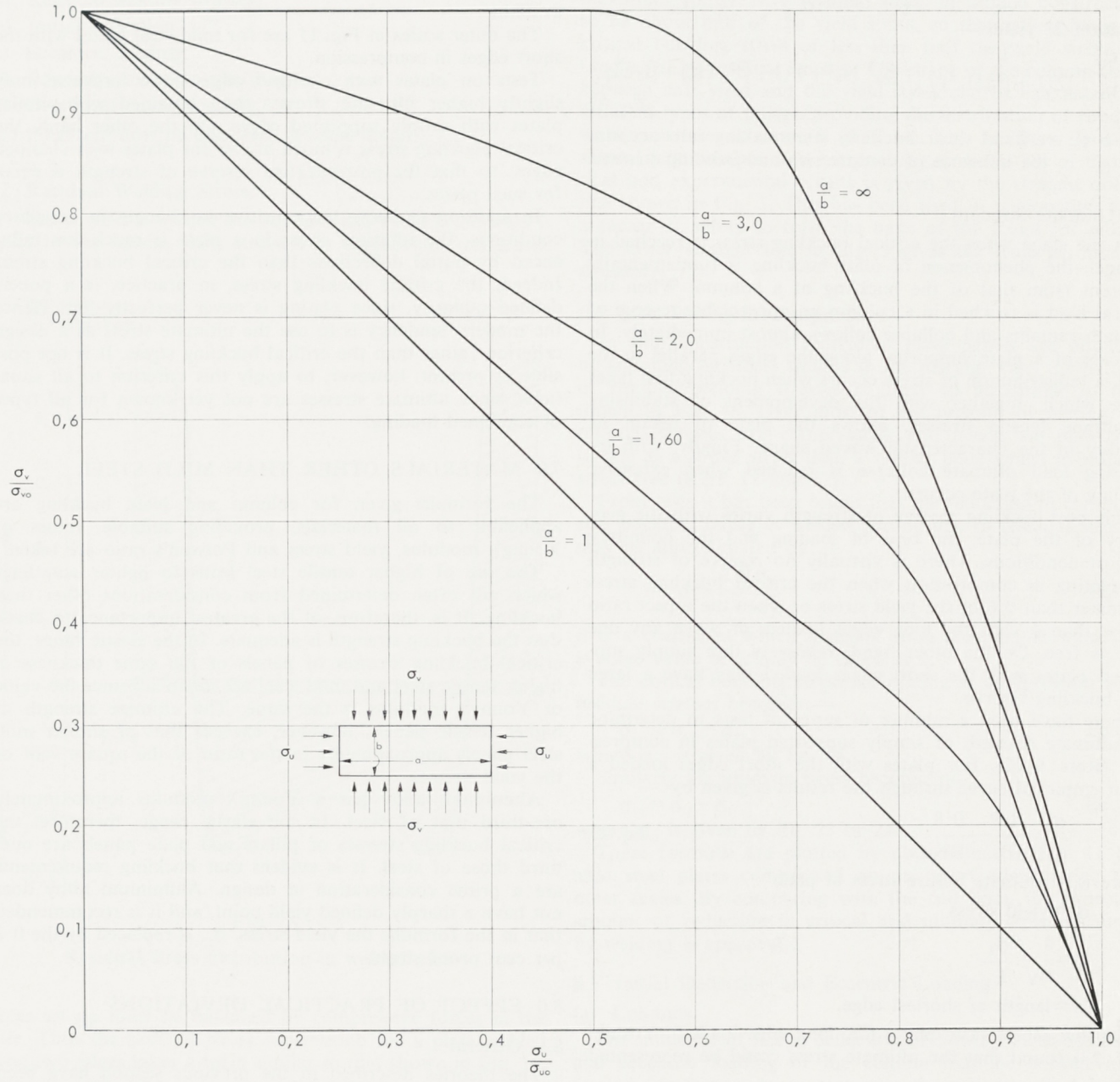



FIG. 15

Interaction curves for plate panels under bi-axial compression.

(v) Panels subject to Combined Shear, In-Plane Bending and Compression

The interaction curve for combined shear, bending and compression may, with sufficient accuracy, be approximated by:—

$$\frac{\sigma}{\sigma_{co}} + \left(\frac{\sigma_b}{\sigma_{bo}}\right)^2 + \left(\frac{\tau}{\tau_{oc}}\right)^2 \leqslant 1 \qquad \text{Eq. 21}$$

Any combination of stresses in one direction may then be calculated.

Introducing the non-dimensional parameters:—

$$\beta_a = \frac{\sigma}{\tau} \quad \beta_b = \frac{\sigma_b}{\tau} \quad H_a = \frac{\tau_{co}}{\sigma_{co}} \quad H_b = \frac{\tau_{co}}{\sigma_{co}}$$

Equation 21 yields:—

$$\frac{\tau_{cr}}{\tau_{co}} = \frac{1}{2(1+\beta_b^2 H_b^2)} \left\{ \sqrt{\beta_a^2 H_a^2 + 4(1+\beta_b^2 H_b^2) - \beta_a H_a} \right\} \qquad \text{Eq. 22}$$

where $\tau_{cr}$ = critical shear buckling stress taking into account the influence of compressive and bending stresses.

6.5 Ultimate Strength

At the stage when the critical buckling stress is reached in a panel, the phenomenon of plate buckling is fundamentally different from that of the buckling of a column. When the critical load is reached in a column no appreciable reserve of strength remains and collapse follows almost immediately. In the case of a plate supported along the edges parallel to the load, a redistribution of stress occurs when buckling first takes place which, together with the development of stabilising membrane tensile stresses, allows the plate to regain its stability in the characteristic waved shape. Finally, with increasing load ultimate collapse is reached when extensive yielding of the plate occurs.

This post-buckling reserve of strength varies with the geometry of the plate, the type of loading and the boundary support conditions. There is virtually no reserve of strength for plating in compression when the critical buckling stress is greater than 0·6 of the yield stress or when the aspect ratio is less than $\frac{1}{4}$ with the long edges loaded, or when any one edge is free. On the other hand, relatively thin simply supported plates with the short edges loaded may have a large post-buckling reserve.

There have been a number of series of tests to determine the ultimate strength of simply supported plates in compression (Refs. 9–12). For plates with the short edges loaded a mean empirical curve through the results is given by:—

$$\frac{\sigma_u}{\sigma_y} = \frac{1{\cdot}9}{B} - \frac{0{\cdot}8}{B^2} \qquad \text{Eq. 23}$$

where $\sigma_u$ = ultimate failure stress of plate

$\sigma_y$ = yield stress

$$B = \frac{s}{t}\sqrt{\frac{\sigma_y}{E}}$$

s = length of shortest edge.

For low aspect ratio plates (i.e. long edge loaded), Yoshiki (Ref. 13) found that the ultimate stress could be represented by:—

$$\frac{\sigma_u}{\sigma_y} = \frac{1{\cdot}77\,\alpha^{0{\cdot}78}}{B} \qquad \text{Eq. 24}$$

where $\alpha$ = aspect ratio.

Eq. 23 is plotted in Fig. 11 to a base of $\frac{s}{t}\sqrt{\frac{4\sigma_y}{kE}}$. By taking the plate factor, k, from Fig. 8, this curve may also be used for low aspect ratio plates, since the results are then nearly equivalent to Eq. 24. The critical buckling curve is also plotted for comparison. In the inelastic region, there is in practice no distinction between the critical buckling stress and the ultimate stress and the two curves are in reasonable agreement. Nevertheless, the inelastic portion of the critical buckling curve is useful, since it covers a wider range of loading and support conditions than the ultimate strength formulations at present available.

The outer scales in Fig. 11 are for mild steel plates with the short edges in compression.

Tests on plates with clamped edges have indicated only slightly higher ultimate stresses than obtained with similar plates with simply supported edges. On the other hand, the critical buckling stress is much higher for plates with clamped edges, so that the post-buckling reserve of strength is small for such plates.

In addition to being less sensitive to changes in boundary conditions, the ultimate stress in a plate is much less influenced by initial deflections than the critical buckling stress. Indeed, the critical buckling stress, in practice, is a poorly defined quantity, since plating is never perfectly flat. Hence the modern tendency is to use the ultimate stress as a design criterion rather than the critical buckling stress. It is not possible at present, however, to apply this criterion to all situations, since ultimate stresses are not yet known for all types of combined loading.

## 7.0 MATERIALS OTHER THAN MILD STEEL

The formulæ given for column and plate buckling are applicable to all materials, providing suitable values of Young's modulus, yield stress and Poisson's ratio are taken.

The use of higher tensile steel leads to lighter scantlings which are often determined from considerations other than buckling. It is, therefore, of the greatest importance to check that the buckling strength is adequate. In the elastic range, the critical buckling stresses of panels of the same thickness in higher tensile steel and mild steel are identical, since the value of Young's modulus is the same. The ultimate strength of higher tensile panels, however, exceeds that of similar mild steel panels approximately in the ratio of the square root of the yield stresses.

Aluminium alloy has a Young's modulus approximately one-third that of steel. In the elastic range, therefore, the critical buckling stresses of pillars and plate panels are one-third those of steel. It is evident that buckling requirements are a prime consideration in design. Aluminium alloy does not have a sharply defined yield point, and it is recommended that in the formulæ the yield stress, $\sigma_y$, is replaced by the 0·2 per cent proof stress.

## 8.0 EFFECT OF PRACTICAL DEVIATIONS

8.1 General

The theories described in the previous section have been derived on the usual assumptions that the material is homogeneous and that the structure, be it column or plate, is initially straight or flat. Furthermore, solutions are given for

boundary conditions chosen for their mathematical convenience rather than their realism. Since in practice the structure is built up from a welded assembly of plates and rolled sections, considerable deviations from these idealistic conditions occur, and as explained in the introduction may have a significant effect on the actual behaviour of the component. Whilst it is now mathematically feasible to introduce all such parameters into the buckling calculation, it is generally too complex for practical design purposes, and therefore the major factors only will be included directly whilst the minor factors are more conveniently taken care of by an appropriate factor of safety.

The principal factors are:—

(a) Residual welding stresses.

(b) Initial deflection.

(c) Eccentric loading.

(d) Boundary restraint conditions.

(e) Combined lateral loading.

and these will now be discussed in some detail.

### 8.2 Residual Welding Stresses

When a weld is cooled the residual stress along the weld is equal to the tensile yield stress. For equilibrium the tensile forces set up must be balanced by compressive forces in the plate. Thus the residual stress distribution for a plate welded along two edges takes a form similar to that shown in Fig. 16, where the total area under the curve is zero.

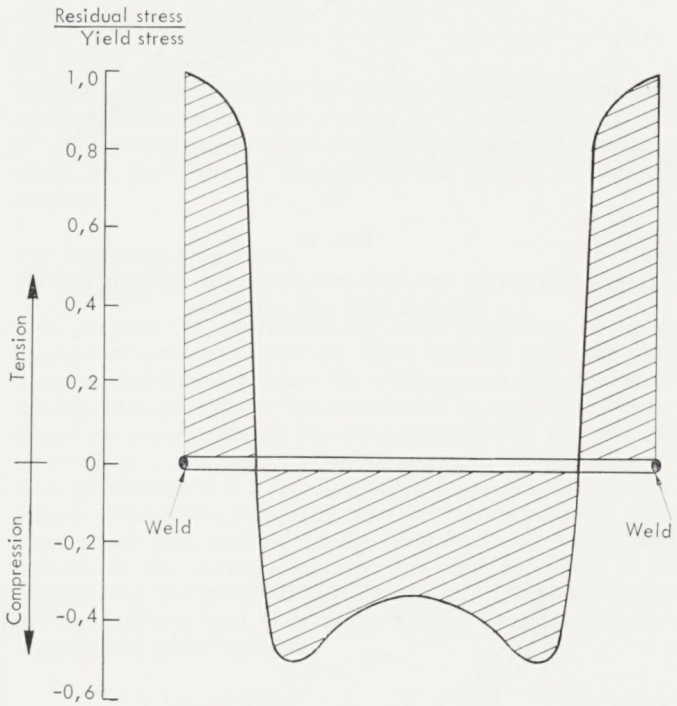



FIG. 16

Residual stress distribution in welded plate.

The effect of such residual stresses on the behaviour of steel pillars and plating in compression will be briefly described.

(a) Steel Pillars

In the following it is assumed that the pillars are so proportioned that local instability is prevented.

If the compressive loading on a welded pillar is gradually increased, the portion of the section which has the highest compressive residual stress reaches the yield point first. This part is then unable to withstand any further increase in load and the effective inertia of the pillar becomes that of the remainder of the cross-section. As the loading is increased further, regions with lower compressive residual stresses begin to yield and the effective inertia reduces until the pillar reaches the critical state at which buckling takes place.

Investigations show that it is reasonable to assume the maximum compressive residual stress in welded construction to be about half of the yield stress, so that pillars having a critical buckling stress of less than half the yield stress are unaffected by residual stresses. The shape of the column curve between half yield and the yield stress can be calculated for different types of pillars, providing the distribution of residual welding stresses is assumed (Ref. 14). This has been done for several pillar shapes, and reasonable representation of theoretical and experimental results is given by the straight dotted line shown in Fig. 3. This has been used in conjunction with a factor of safety to form the basis of the Rules for pillars. The lower straight line in Fig. 3 gives the Rule permissible stresses.

(b) Steel Plating in Compression

In ship construction individual plate panels are bounded by stiffening members welded to the plating. Thus the pattern of residual welding stresses is likely to be similar to that shown in Fig. 16. Over most of the breadth of plating the residual stresses are compressive, and hence the plate will buckle at a lower stress than a similar plate which is initially stress free (Refs. 11 and 12).

From tests it has been found that the reduction in compressive buckling stress in welded plating due to residual stresses may be approximated by:—

$$\sigma_r = \frac{2\beta\sigma_y}{b/t} \qquad \text{Eq. 25}$$

$\beta$ is a coefficient which depends upon the type of weld. An average value of $\beta$ may be taken as 3.

The critical buckling stress for plating in compression with residual stresses becomes:—

$$\sigma_{cr} = \sigma_{co} - \sigma_r \qquad \text{Eq. 26}$$

where $\sigma_{co}$ is given by Eq. 14.

Similarly the ultimate stress becomes:—

$$\sigma_{ur} = \sigma_u - \sigma_r \qquad \text{Eq. 27}$$

where $\sigma_u$ is given by Eq. 23 or 24.

These formulæ are plotted by dotted lines in Fig. 11 for mild steel plates compressed on the short edges, using the outer scales. By comparing with the full lines, the expected amount of reduction in critical and ultimate stresses caused by welding is apparent.

### 8.3 Initial Deflection and Eccentric Loading

(a) Columns

The influence of initial deflection or bowing of the column and eccentric loading of the column may be conveniently treated together, since in each case the primary effect is the transmission of an additional moment to the column. Assuming the initial deflected shape as a half sine wave, this results

in an additional sinusoidal bending moment in the former case, and a constant bending moment in the latter.

The nett effect of this additional moment is the magnification of the deflections and stresses derived under concentric loading by an amplification factor K equal to $\frac{1}{(1-P/P_E)}$ for an initially bowed column (a), and $\frac{1}{(\cos\frac{\pi}{2}\sqrt{P/P_E})}$ for an eccentrically loaded column (b), from which the maximum stress in the column may be derived as:—

$$\sigma_{max}=\frac{P}{A}+K\frac{M}{Z} \qquad \text{Eq. 28}$$

where P = applied load

$P_E$ = Euler critical buckling load.

A = cross-sectional area

M = bending moment = Pe

Z = section modulus

K = amplification factor (a) or (b)

e = initial deflection or eccentricity

Using this relationship Shanley has devised the following interaction equations for the two cases which are also shown plotted in Figs. 17 and 18 taken from Ref. 15.

(a) $R_b=(1-R_c)\,(1-\eta\,R_c)$ Eq. 29

(b) $R_b=(1-R_c)\cos\left(\frac{\pi}{2}\sqrt{\eta\,R_c}\right)$ Eq. 30

where $R_b=\frac{M}{M_o}$ $M_o$ = plastic moment at collapse

$R_c=\frac{P}{P_o}$ $P_o$ = maximum compressive load at failure

$= A\,\sigma_o$ ($\sigma_o$ from Eq. 6)

$\eta=\frac{P_o}{P_E}$ $e_o=\frac{M_o}{P_o}$

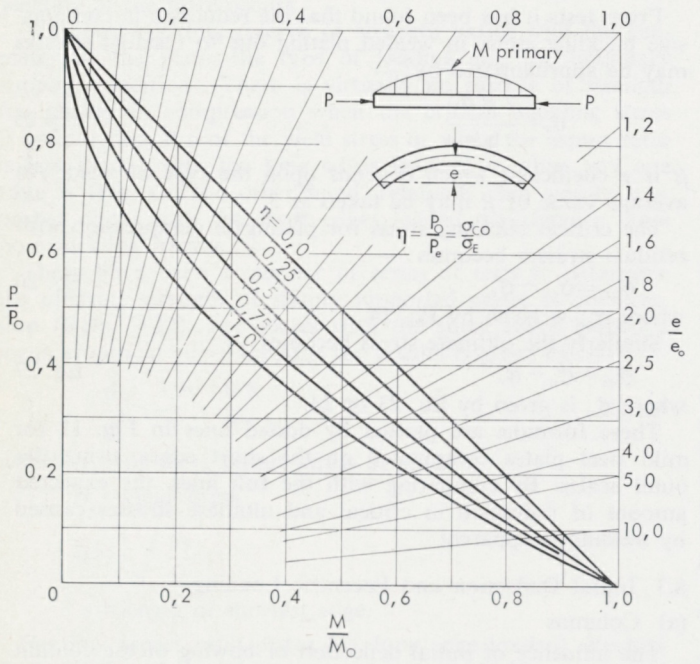



FIG. 17

Interaction curves for columns with initial deflections.

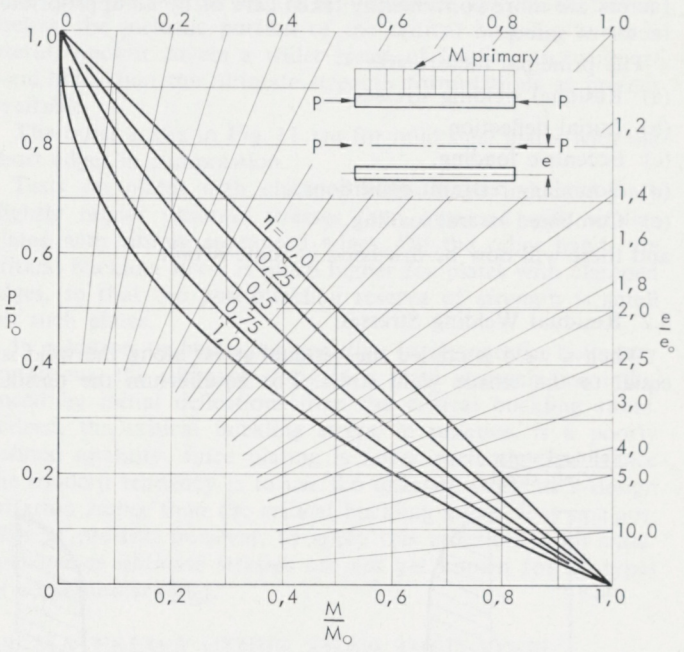



FIG. 18

Interaction curves for eccentrically loaded columns and for columns with end moments.

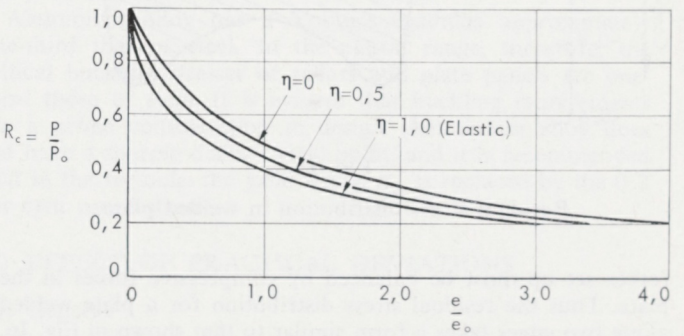



FIG. 19

Reduction factors for columns with initial deflections.

The serious reduction in column strength caused by such eccentricity may be gauged from Fig. 19 where $R_c$ represents the relative decrease in efficiency. These factors account in some measure for the early discrepancies between theory, experiment and practice, and emphasise the need for good workmanship and proper alignment of compression components in ship structures if premature failure is to be avoided.

Fig. 18, or Eq. 30 may also be used to determine the critical buckling stress of a column subject to end moments, M, in addition to axial compressive loading. The end moments may result from the column being attached to end supporting members which are themselves loaded. The constraining effect of the supporting structure is taken into account by using an effective span in the determination of $P_o$, as described in Section 3.3. The failure load under axial load alone, $P_o$, is normally that for flexural buckling (Eq. 6). It may, however, be determined for torsional buckling (Section 4) or local buckling if these modes cause failure at a smaller load than that of the flexural buckling mode.

Where the end moments are not equal or are of opposite sign, the equivalent value of M may be determined from the following formula: —

$$M = \sqrt{0{\cdot}3\ (M_a^2 + M_b^2) + 0{\cdot}4\ M_a\ M_b} \qquad \text{Eq. 31}$$

where $M_a$ and $M_b$ are the end moments.

The bending stresses due to the end moments should, of course, also be checked.

(b) Plates

Whilst initial deflection of a plate will serve to magnify the deflections under axial loading by a magnification factor as shown for columns, the effect is not so critical since its effect on the ultimate strength of the plating is generally minimal.

8.4 Boundary Conditions

(a) Columns

In practice the mathematically ideal conditions of simple support or complete fixity are never realised, since the pillar is not an individual member but a component of a total structural framework system. In consequence its end fixity is determined by the rigidity of the other members of the structure to which it is attached. The effective length of the pillar will then lie between $0{\cdot}5\ l$ and $l$ provided by these idealistic conditions. Whilst the true fixity may be calculated from equations which take account of the rotational and translational stiffness of the surrounding structure, this procedure is too cumbersome for practical application, and therefore the following standards have been adopted based upon investigations utilising the above methods.

| | |
|---|---|
| Hold pillars ending upon a double bottom structure | $l_e = 0{,}65l$ |
| Tween deck pillars | $l_e = 0{,}80l$ |

(b) Plates

It has already been stated that the critical buckling stress factor k is dependent upon the constraint provided at the boundaries of the plate. In practice, however, the plate elements under consideration in ship structures are part of a continuous stiffened sheet, and therefore the boundary fixities are dependent upon the relative stiffness of the sheet in flexure and the torsional stiffness of the stiffeners forming the boundary. In both cases these are relatively small, and this, coupled with the fact that the adjacent panels may be adopting a buckling configuration themselves, the support condition realised has been shown to correspond to simple support more than any other. In all plate problems associated with ship structure a condition of simple support is assumed, except where the edge is completely free. Whilst this may be considered conservative in some instances, it should be noted that ultimate strength of a stiffened continuous plate is almost independent of the boundary restraint.

8.5 Combined Lateral Loading

(a) Columns

The true beam/column is rarely encountered in ship structures. In most cases the scantlings of the beam are derived under lateral loading conditions only and the influence of axial loading reflected in the value of the allowable stress. The nett effect of the latter load is an amplification of the stress in a manner similar to that described under Section 8.3, and where a rigorous solution is required interaction formulæ of the type shown may be utilised.

The closest approximation to the beam column is the longitudinal framing of the bottom shell, which could be subjected to relatively high axial loading due to bending of the hull girder in association with lateral loading due to hydrostatic pressure.

(b) Plating

Although the theory given in Section 6 refers to plating under in-plane loading only, in practice however the plates may be subjected to lateral loads from hydrostatic pressure, i.e. bottom shell.

In such a case the deformed shape of the panel will be governed by the lateral loading until the in-plane load exceeds the critical value when the conventional buckling pattern will be imposed upon the plate.

In consequence, the latter pressure if severe may delay the onset of buckling by a small amount, but for practical purposes this effect may be neglected and the critical buckling stress derived considering in-plane loading only.

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